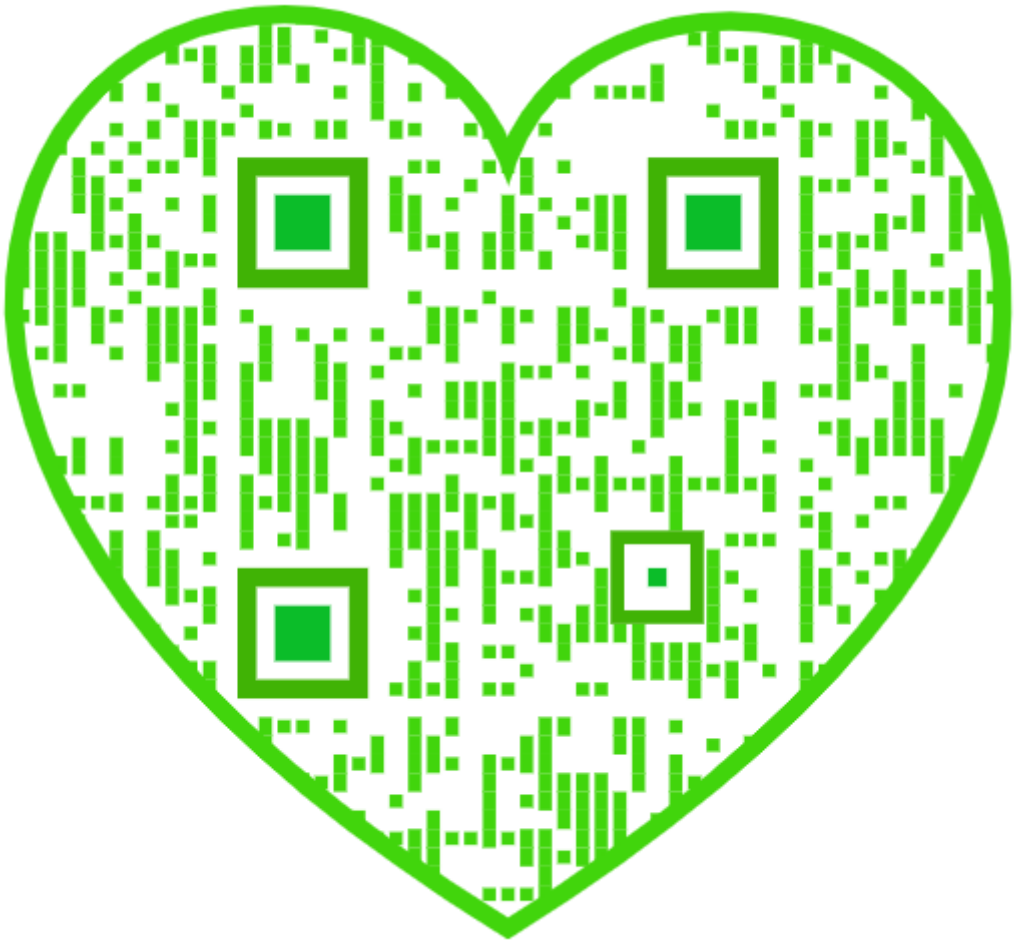
GEOGRAPHY OF THE CENTRAL ANDES

ALAN G. OGILVIE

AMERICAN GEOGRAPHICAL SOCIETY

MAP OF HISPANIC AMERICA PUBLICATION NO. 1



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A Handbook to Accompany the LA PAZ Sheet of the Map of Hispanic America on the Millionth Scale

BY
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WITH AN INTRODUCTION BY
ISAIAH BOWMAN

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ACKNOWLEDGMENT

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PREFACE

This regional account of an important part of the Central Andes and the first (provisional) edition of the map representing the area have been compiled simultaneously as the result of an effort to draw together much scattered information. Materials for map and book have been gathered from sources which vary widely in character and quality. The data utilized in the map, and the method of its construction, are discussed in some detail in Part I. The bibliography records most of the sources of material for the book.

Existing scientific data are probably above the average for South American areas of this extent in both quantity and quality; but, as a rule, they relate only to small parts of the country. Moreover, we can turn to no systematic description of the whole territory covered by the map. And modern geography requires more than mere description; it demands that genetic relationships be brought out. This fact has been kept in view in writing a book which, because of the present state of knowledge, is a provisional edition, like the map that it accompanies.

The reader will quickly appreciate that within the area discussed there are several strongly contrasted natural regions, and he will surely ask himself what is the total extent of each. For, in fact, all of the more important of them extend far beyond the map limits. A diagram has therefore been placed at the end of Chapter I showing the relation of the various natural regions discussed to the sheets of the millionth map in general and to the La Paz sheet in particular. Thus it will be seen that many of the general observations which are made in this handbook would apply equally well in the description of a number of different map areas.

I have great pleasure in acknowledging my indebtedness to a number of colleagues for their assistance. The section on soils was written after consultation with Dr. C. F. Marbut, of the

United States Bureau of Soils, who kindly gave me his opinion on the probable conditions prevailing in the several regions. In collecting data for Chapter VIII, I have had the advantage of consulting Drs. F. M. Chapman, H. E. Anthony, R. C. Murphy, and other officers of the Department of Zoölogy in the American Museum of Natural History. Dr. Murphy has also read critically the manuscript of this chapter.

My thanks are due to Dr. Isaiah Bowman, who placed at my disposal field notes, photographs, maps, and personal information, much of it unpublished, that he had gathered on several expeditions to the Central Andes; to Dr. George M. McBride for collecting most of the historical material included in Chapter IX and Appendix B, as well as for writing Appendix A; and to Dr. Gladys M. Wrigley, who permitted me to use her unpublished work on settlements and routes in the coastal zone.

Alan G. Ogilvie.

INTRODUCTION

By Isaiah Bowman

In 1920 the Society announced a plan for Hispanic-American research of which this book and the La Paz sheet on the scale 1: 1,000,000 are among the first results. Field studies in the Central Andes in 1907, 1911, and 1913 had yielded me first-hand knowledge of the geography of highland Peru and Bolivia as well as the highly contrasted lowlands on either side, and this fact, together with the diversified character of the region, was the chief inducement to start the plan with the production of the La Paz sheet. Ten other sheets are in course of compilation or reproduction. They range in position from the peninsula of Lower California to the Gran Chaco of southeastern Bolivia. It is planned to complete the sheets in natural groups if the plan can be supported to that extent. In time, handbooks like the present one will summarize the regional aspects of the geography. Until the sheets of such natural groups are produced each map will be accompanied by a leaflet describing the cartographical sources which support it.

The production of the first sheet has revealed a surprising amount of data, bearing upon the general geography no less than upon the map, that has been wholly unknown to geographers hitherto. To such an extent is this true that I know of no more fruitful means of advancing a knowledge of the Hispanic-American realm than the plan upon which we have embarked. Having conducted exploratory expeditions, I am aware of the lure of field work and of its value to science. But there comes a time in the history of every subject when a broad and critical synthesis may be of even more value. At this juncture the millionth map supplies an indispensable medium for synthetic and comparative studies of a high order. The handbooks that form a part of the plan depend inevitably upon field work to be carried on from time to time as circumstances permit—field work that is guided

by knowledge gained in the compilation of maps from so many sources. In time this will bring us to the point where a general geographical study of Hispanic-America can be made upon a sound scientific basis.

Parallel with these activities the Society has conducted others that may be enumerated here. There has been produced a map of Hispanic-America on the scale of 1: 6,000,000, or a little less than 100 miles to the inch. It is drawn from nearly 250 sources, including a large number of original surveys. It shows railways, drainage indicated as surveyed or unsurveyed, international and administrative boundaries, and towns in graded sequence down to those with a population of 4,000. It is produced in three sheets which can be handled separately or assembled to make a wall map. Upon it in a separate edition will be represented in color the state of knowledge respecting the cartography of Hispanic-America, the population density plotted on a rational basis from most recent census returns, and eventually soils, forests, and the like. There has also been completed a *List of Maps of Hispanic America. (I) Maps Contained in Periodical Publications*, published as a volume of bound typewritten sheets in a very small edition. A second part of the work (II) is a list of miscellaneous maps in books and in sheet form, and a third (III) a list of official maps. The maps are arranged chronologically by countries. The second part of the work is well advanced and now consists of 10,000 entries chiefly of historical value; the third remains to be done, except in so far as the regular map collection of the Society includes portions of it.

As a basis for physiographic research the Society has just published in book form *A Catalogue of Geological Maps of South America*, with an index map, as No. 9 in its Research Series. An intensive study of the Mexican land system is in press and one on Argentine colonization is in preparation. The last-named is a parallel study to *Recent Colonization in Chile* published in 1921 as Research Series No. 6.

The whole Hispanic-American program is necessarily based on maps because no thorough and systematic collation of such mate-

rial whether published or unpublished has ever been attempted. It follows that the student of the human geography of Hispanic-America is frustrated at every turn by the paucity of a given map collection, or its unordered state, or the highly unequal quality of its parts. It is one of the aims of the Society to substitute for this great deficiency a set of maps of high quality so that from them and the collateral knowledge gained in their production there shall flow a series of truly scientific papers in the field of regional geography.

PART ONE

CHAPTER I

THE LA PAZ SHEET OF THE 1: 1,000,000 MAP

It was thought worth while to compile the La Paz sheet of the millionth map for two main reasons; first because from scientific and practical standpoints it is important to have at the present time the best possible map covering a complete section of the Andes at its widest part. This it is hoped will be furnished by the La Paz sheet and the Santa Cruz sheet to the east of it. And secondly, because a number of surveys and reconnaissances have been made in the areas of both sheets since publication of the most recent general maps of the region.

No claim is implied that the present provisional edition of the map is uniformly reliable in all its parts. It represents careful compilation from all the maps and documents which could be collected in the circumstances. All published maps as well as the results of a considerable number of unpublished reconnaissance surveys have been studied.

Perhaps the most serious obstacle to scientific compilation has been the lack in large areas of geographical positions of unquestionable reliability, a condition especially serious in regard to longitudes. In this respect the western part of the map is reasonably reliable, because based on a good hydrographic survey of the coast, as well as on the records of the astronomical observatory at Arequipa. But east of the Western Cordillera the difficulties increase. The geographical positions of several towns are given by Bolivian official publications, but the positions are recorded differently, the variations being small in latitude and wide in longitude. Moreover, they differ considerably from the observations of earlier surveyors such as Pentland and Minchin. It was most desirable to obtain if possible a continuous skeleton

from the Pacific Coast to the eastern foot of the Andes, and, so far as is known, there is but one source for such a series. Colonel P. H. Fawcett, in proceeding to the eastern boundary of Bolivia in 1913 to carry out survey work there on behalf of the Bolivian government, carried a series of observations from Puno on Lake Titicaca (whose position is known relative to Arequipa) right across to the Brazilian boundary; and most of the positions he recorded fall within the La Paz and Santa Cruz sheets. In making use of these points, however, another difficulty arose. Colonel Fawcett published his results in 1915 in a preliminary map of small scale (1: 3,000,000) and with no records other than the plotting of the points. A tracing of the original of part of this map, on a larger scale, was obtained by the courtesy of the Royal Geographical Society of London; but beyond this no information regarding the observations on the map was forthcoming, as Colonel Fawcett had already started on a further exploration in the heart of Brazil. It was therefore decided to accept his positions only where they agreed closely with those of other surveys, and where no original surveys were available. As regards the La Paz sheet, one of the chief innovations was the movement of Cochabamba some 13 minutes to the east of its position on most other maps. The co-ordinates given in the *Annuario Estadístico y Geográfico de Bolivia* were accepted, as they agreed very closely with the position of the city on Fawcett's map. The positions in the southern part of the Altiplano are derived in the main from Minchin's surveys.

The coast line was surveyed in 1836 by H. M. S. *Beagle*,[1] and the British charts based on this survey together with the Chilean plans covering a number of small areas have furnished the coastal and hydrographic data for the La Paz sheet.[2] All the recent compiled maps save one have followed these charts. The exception is

[1] The work was actually carried out by Usborne during the winter of 1835–1836 in the *Constitución* which was used as a tender to the *Beagle*.

[2] The coast line, however, was adjusted to the longitude of Iquique, as given on the map of the Departamento de Tarapacá, 1: 25,000, Oficina de Mensura de Tierras, 1918. The longitude of the lighthouse at Iquique is there given as 70° 10′ 27″ W., while British Admiralty Chart No. 1278 places it at 70° 11′ 48″ W., a difference of 1′ 21″.

the compilation made at Arequipa in 1912 by T. A. Corry of the Ferrocarril del Sur del Perú. In this map the entire coast line northwest of Arica exhibits many variations from the hydrographic charts, the most noticeable difference being in the trend for the first 25 kilometers north of Ilo which is almost due north instead of north-northwest as on the charts. This has the effect of placing a large bight between Ilo and Punta de Bombón. As it proved impossible to ascertain the nature of the observations upon which these changes had been based, the coast line of the *Beagle* survey has been allowed to stand.

The only single survey covering a large area is that of the Chile-Bolivia Boundary Commission, which was based upon a triangulation of all the principal peaks of the Western Cordillera south of latitude 17° and was connected to the coast at Arica and at Iquique, just south of the map area. The sheets were published between 1908 and 1912 on the scale of 1: 250,000. They contain a very large number of altitudes. There are three smaller areas of survey based on triangulation. The district between Lake Titicaca and La Paz was surveyed by a French commission in the service of the Bolivian government in 1902–1903. Access was obtained to a copy of part of this map, which, however, has never been published. Overlapping this survey is Conway's triangulation and survey of the Cordillera Real made in 1898 and published in final form in 1900 on the scale of 1: 500,000.

The triangulation and survey made about 1906 of the Pampa de Salinas east of Arequipa has also been used. The detailed maps of the nitrate district in the southwest corner had been incorporated in the Chilean official map 1: 500,000 mentioned below, and that source has been used.

In the category of reliable traverses based upon a series of astronomical observations with chronometer longitudes, the most important are those of Minchin across the Altiplano and thence southeastward to Potosí, carried out about 1875. Minchin's points, adjusted in longitude to agree with the accepted position of Oruro and with that of Sucre determined by time signal by Steinmann and Hoek, have been accepted as a skeleton in the

southeastern part of the sheet. In part this was supplemented by an excellent unpublished compass traverse by A. P. Rogers from Challapata to Colquechaca and by others from Oruro through San Pedro to Colquechaca and from Potosí to Challapata, both by A. Stiles. Of other compass traverses, use has been made of that of Steinmann, Hoek, and von Bistram entering the area from the east and reaching nearly to La Paz. This long traverse —made in 1903–1904—rests upon few fixed points and has been used mainly for its topographic detail. Two compass sketches of mountain groups—the Quimsa Cruz and the Cordillera northwest of Cochabamba—were made by Herzog in 1911, and these have been accepted almost in their entirety. Unfortunately there are few checks upon the accuracy of their scale, but they are believed to give a good representation of the mountains, shown by carefully drawn form lines which agree with the descriptions of the land forms. For the eastern slope of the Cordillera Real north of the Quimsa Cruz range, data were furnished by a compass reconnaissance made in locating the Yungas railway, a stadia survey for the railway when located, a geological reconnaissance of the foothills, and a road survey. The La Paz River in its upper section appears on Conway's map. For the section of the Río Beni below Coroico a stadia reconnaissance for a projected railway was used, while the intervening portion has been taken from the survey made by Heath between 1879 and 1881 and supplemented later by Garcia Mesa. Of railway surveys those of the Arica-La Paz and the Huaqui-La Paz lines give a valuable check upon longitudes in the Altiplano, while the map of the Oruro-Cochabamba railway furnished much additional topographic information derived from reconnaissances on both sides of the line. The shore lines of Lakes Titicaca and Poopó have been taken, save for details, from the surveys of Neveu-Lemaire of the Créqui-Montfort expedition; and the Desaguadero River from the survey of Bergelund made in 1892 for the Peruvian Corporation.

Previous compilations have had to be used in areas for which no original surveys were available. The compilers of these maps,

which are included in the list given below, undoubtedly had access to certain sources which the compiler of this map has not had. For instance, Huot, the cartographer of the Créqui-Montfort expedition, in compiling his "Carte des Andes Centrales," 1:750,000, which for most parts is the best general map of the Central Andes, was able to use the topographic information brought back by that expedition; and in Peru, Corry had information which enabled him to modify Raimondi's map in several respects. It is unfortunate that in most compiled maps there is no systematic discrimination between the known and the unknown; and this is especially true of maps published in South America. The conventional signs of the International Map, which have been adopted, enable us to make this important distinction quite clear.

In the case of areas in which we are reasonably sure that no surveys have been made, we have had to interpret written accounts of the country in the light of our general knowledge of the main geological structure and the way in which it controls the surface features in this and other parts of the Andes. Thus in the case of the Eastern Cordillera we have drawn, without accurate knowledge, river valleys which are known to exist, as well as the very approximate contours between them. We have rarely followed exactly the river courses from any of the extremely variable previous compilations but have boldly inserted lines which we believe to have in general a more probable location than those of previous maps of these parts. We believe this action to be justified, provided the method be clearly stated, as it is in this text and in the reliability diagram on the border of the map. Except in the very few areas which have been contoured in the field, approximate contours have been drawn in the manner described. The advice of those who have seen the areas or others undoubtedly similar has been sought constantly. Thus, while the contours over much of the map are very approximate and while neither they nor the drainage lines have the detail which only survey can give them, yet we believe that the *character* of the contours is essentially correct. The kind of modification

which is made by survey upon the generalized approximate contours may be judged by a comparison on the map of the Pampa de Salinas (surveyed) east of Arequipa with the Pampa de Viscachas (unsurveyed) to the southeast of it; or again in the plateaus of the Eastern Cordillera by comparing the general hill forms (unsurveyed) with the very small surveyed portions northwest of Uncia and east of Chayanta.

As mentioned above, geological knowledge has been utilized in determining the trend of surface features. In the case of the northeastern corner of the area it is probable that the topography is represented too diagrammatically; but, on the other hand, it is believed that on the Altiplano between the two Cordilleras subsequent mapping will bring out more clearly the parallel arrangement of ridges and valleys. The difference of treatment is based on the very different amount of topographic knowledge of the two areas. The lower ranges of the Andes east of the Río Bopi are completely unsurveyed save for one compass traverse by Orbigny, and, while Orbigny's descriptions are valuable, his compass observations seem to be unreliable. But the Altiplano, on the other hand, has been mapped from a number of traverses which have been accepted in general. But these contain little detail, and in an area of such slight relief it is the smaller features which bring out the topographic pattern. Similarly in the high plateaus west of Lake Titicaca, Raimondi's map has been copied, and it is not known how much surveying this explorer did in the area. But it seems likely that a more detailed knowledge would reveal a marked regularity of valley direction conforming generally to the geologic strike of the sedimentary rocks which in all probability are exposed in much of the area.

The compilers have diverged somewhat from the requirements of the International Map Committee in regard to the contours. The "principal contours" demanded, which are all limits of hypsometric tints, have been inserted. But the color scale has been extended by providing an additional tint for land above 5,000 meters, this being necessary to bring out the higher mountains. No separate color is provided for the seven small areas

over 6,000 meters, most of these being above the snow line. The peculiar nature of the relief called for special treatment of the intermediate contours. The relatively slight but yet important relief at high altitudes demanded that these be inserted at every 200 meters above 3,000 meters in accordance with the international scheme. This has been done everywhere throughout the sheet for all parts above 3,000 meters (save in the Cordillera Real in a few spots where there was not room to draw the lines). Below 3,000 meters, where the postulated contour interval changes to 100 meters, the slopes in many parts of the map —especially in the east—are so steep that contours at this vertical interval would obscure the hypsometric tints. Moreover, in many areas the data are insufficient for their insertion. These contours have therefore been inserted only where they were called for to bring out special features. But the 100, 200, 500, and 700 meter lines, which are required as the limits of tinted areas, have been drawn throughout.

Not the least difficult part of the compilation of such a map as this is the selection of names. Names of all sorts occurring in original surveys used have been accepted with certain alterations in spelling. Otherwise names of physical features have for the most part been culled from the compiled maps mentioned in the list, and in cases where these maps disagree preference has been given to the map whose source seemed to be most authoritative in the particular area in question. Some help was also obtained in this work from the various official gazetteers of Bolivia, Chile, and Peru. In regard to the names of towns, villages, and settlements an effort was made to base the selection in the main upon the census reports of the three countries with some additional aid in the case of Bolivia, from the "Diccionario Geográfico de Bolivia"; the intention being to eliminate names which applied to the smallest centers of population, such as isolated farms, and to obtain a more or less rigid grading in the importance of names. But the effort proved almost fruitless in that the documents mentioned give insufficient details. The only other course has therefore been followed, namely, to insert

as many place names as possible without marring the other features of the map. Moreover, the grading indicated in the legend can be accepted only as generally accurate.

All names on the La Paz sheet are either Spanish or Indian, and of the latter all save a small number on the eastern slopes of the Andes are either Quichua or Aymará. The Indian names are given in the conventional Spanish transliteration. But it must be remembered that the Spanish alphabet has no means of representing accurately a number of Indian sounds. This is specially true of the gutturals, and the compilers have diverged from Spanish forms in one respect, to introduce the *kh* as representing more accurately one class of Indian consonant.

The bathymetric lines were interpolated from the soundings given on the charts supplemented by soundings from the volumes published between 1910 and 1920 in connection with the Carte Générale Bathymétrique des Océans. Submarine cables have been inserted in accordance with official data.

MAPS USED IN THE CONSTRUCTION OF THE LA PAZ SHEET[2]

1. La Laguna de Titicaca and the valleys of Yucay, Collao and Desaguadero in Peru and Bolivia by J. B. Pentland from surveys 1827–30. Published as a British Admiralty chart.
2. Carte générale de la République de Bolivia, by Alcide d'Orbigny from itineraries 1830–33. Ca. 1:1,575,000. Published in his "Voyage dans l'Amérique méridionale," Paris, 1835–47
3. Itinéraries et coupe géologique à travers le continent de l'Amérique du Sud. Ca. 1:250,000. Francis de Castelnau. 1852.
4. Map of part of Bolivia from surveys of John B. Minchin. 1:850,000. Published with a paper by G. C. Musters, *Journ. Royal Geogr. Soc.*, London, 1877.
5. Mapa de los Ríos Beni y Yacuma según las exploraciones del Dr. Eduardo R. Heath, 1879–1881, completado por L. Garcia Mesa. 1:800,000. 1903. (Unpublished.)

[2] The La Paz sheet was compiled under my direction by Mr. William A. Briesemeister of the staff of the American Geographical Society.

6. Part of the Bolivian table land. Ca. 1:1,100,000. By John B. Minchin. *Proc. Royal Geogr. Soc.*, London, 1882.
7. Mapa del Perú. 1:500,000. A. Raimondi. Sheets 29, 30, 31, 32. 1889 onwards.
8. French Admiralty chart 3337. (1894.)
9. The Cordillera Real, Bolivia. From a triangulation and plane table survey (1898) by Sir Martin Conway, and other documents. 1:500,000. *Geogr. Journ.*, Vol. 15, 1900.
10. Plano de la Ciudad de Oruro. 1:10,000. Diccionario Geográfico de la República de Bolivia. Tomo 4. Departamento de Oruro. 1902.
11. Régions des Hauts Plateaux de l'Amérique du Sud. Carte dressée par Victor Huot d'après les Travaux des Membres de la Mission Créqui-Montfort et Sénéchal de la Grange, etc. 1:750,000. Paris, 1903.
12. Part of the survey by the French "Mission Schrader," 1:200,000, between La Paz and Lake Titicaca. Ca. 1904. (Unpublished.)
13. (*a*) Routenkarte der Expedition Steinmann, Hoek und von Bistram in den Anden von Bolivien. 1:750,000.
    (*b*) Umgegend von Cochabamba. 1:3,750,000. Surveyed 1903–04. Published in *Petermanus Mitt.*, Vol. 52, 1906.
14. Proyecto preliminar de un camino de Herradura de la Paz á Puerto Pando por Julio Knaudt. 1:250,000. 1904. (Unpublished.)
15. Carte bathymétrique du Lac Titicaca, 1: 525,000; Carte bathymétrique du Lac Poopó, 1:420,000; dressées par le Dr. M. Neveu-Lemaire. Published in "Les Lacs des Hauts Plateaux," Paris, 1906.
16. Proyecto de Istunchaca. 1:200,000. Reducción del plano del ingeniero Carter del año 1848. Published in *Bol. Cuerpo de Ingenieros de Minas del Perú No. 45*, 1906.
17. Oficina Hidrográfica Chile. Chart No. 128. 1906.
18. Mapa Hidrológico (coast of Peru). 1:1,000,000. In *Bol. Cuerpo de Ingenieros de Minas del Perú No. 45*, 1906.

19. Croquis geográfico de la región estudiada por la Comision Hidrológica de Moquegua, 1:500,000, por H. C. Hurd. In *Bol. Cuerpo de Ingenieros de Minas del Perú No. 39*, 1906.
20. Plano topográfico de la cuenca hidrográfica de la región de Salinas. 1:100,000 and 1:20,000. Published in *Bol. Cuerpo de Ingenieros de Minas del Perú No. 49*, 1907.
21. Surveys of the Comision Chilena de Límites, 3 sheets, 17°–20° S. 1:250,000. 1908 and 1912.
22. Mapa de los Pampas y Borde Occidental de la Cordillera de los Departamentos de Ica, Arequipa, Moquegua y Tacna. 1:500,000. V. F. Marsters. Published in *Bol. Cuerpo de Ingenieros de Minas del Perú No. 70*, 1909.
23. Correccion del Río Rocha. 1:25,000. Julio Knaudt. La Paz, 1910.
24. Plano general del Río Desaguadero. 1:633,000. Julio Bergelund. Published in *Bol. Soc. Geogr. de Lima*, Vol. 26, 1910.
25. Map of the islands of Titicaca. Ca. 1:33,333. Adolph F. Bandelier. Published in "The Islands of Titicaca and Koati," New York, 1910.
26. South Peru and north Bolivia. 1:2,000,000. *Geogr. Journ.*, Vol. 34, 1910.
27. (*a*) Chile. 1:500,000, 2 sheets (17°–21° S.); (*b*) Chile with part of Bolivia. 1:1,000,000. Both published by the Chilean Oficina de Mensura de Tierras. 1910.
28. Reconocimiento de los Ríos La Paz, Palca, Luribay y Araca por R. Capriles. 1:400,000. Direcc. Gen. Obras Publicas, 1911.
29. Mapa telegráfico de Bolivia. 1:2,400,000. 1911.
30. Canalizacion del Río Rocha. 1:100,000. Ca. 1912. (Unpublished.)
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PART TWO

CHAPTER I

GENERAL VIEW

Three events in the physical history of the land covered by the La Paz sheet have been of chief importance in determining the distribution of life and the activities of man in the area.

The first is the upheaval of a block of the earth's crust of such great width and to so great an altitude. From this results a rare atmosphere over most of the surface and a climate which is very dry, save on the eastern slopes of the Andes and which is also cold in all but the two small sections of low altitude. These climatic conditions restrict the natural vegetation, the possibilities of agriculture, and consequently the density of the population; while the great difference of altitude between the highlands and the marginal lowlands discourages movement from one to the other.

The second feature is the mineralization of the rocks forming the cordillera which took place both before and during the upheaval of the highlands. One result of this has been to raise the number of inhabitants considerably above the normal for such a region; moreover, the mineral wealth of these cordilleras has greatly increased their importance to the outside world from the Spanish Conquest right down to our own time.

Thirdly, there is the fact that prior to the great upheaval of the land a large part of it—the eastern section—had undergone a long period of denudation and another large part—the western section—had been covered with great lava sheets. This accounts for the relative smoothness of the greater part of the highland surface. Save for the volcanic cones and occasional residual ranges the core of the high block presents few serious obstacles to free movement, be it of air, plant, beast, or man. Further, it

is to the intensive erosion in the eastern part that we owe the discovery at the surface and the easy mining of the various minerals. All other facts which we shall have occasion to state will prove to be of less general importance than these three.

The section of the Andes between latitude 16° and 20° S. can be described briefly as a greatly elevated peneplane formed upon disordered rocks, mostly sedimentary, with a northwest-southeast strike. The peneplane, which bears an important residual range —the Cordillera Real—near its northeastern edge, is warped down and probably also broken by normal faulting on both margins, forming the two flanks of the Andes; and the central portion of it—the Altiplano—stands at a lower level than its two rims, probably on account of trough faults, thus forming a basin of interior drainage with its lowest portion in the southeast. The western rim of the elevated peneplane has been subjected to warping and fracturing in various parts, so that it is not everywhere as striking a feature as it is, for instance, in the extreme south of the area. Moreover, it is surmounted by an almost continuous chain of volcanic peaks, forming the Maritime Cordillera, while lava flows and volcanic detritus cloak the western margin of the Altiplano. Both flanks of the Andes are deeply scored by valleys eroded during and since the uplift of the land. In the west this dissection is much less complete than on the east, where the rainfall is very much greater. On both flanks, but especially in the east, the summits and valleys bear the marks left by the Pleistocene glaciation. As a result of this dissection the flanks of the Andes are bordered by extensive, gently sloping, piedmont surfaces. On the northeastern side only a small portion of these is included in the area; but on the Pacific side they form a continuous and important band in some parts reaching to the coastal hills. These last represent the broken remnants of a greatly denuded surface formed on disordered rocks, for the most part crystalline. They can probably be taken to be the vestiges of a crustal block now foundered to an abyssal depth in the Pacific Ocean.

On account of the long denudation which preceded the main

uplift of the Andes the geological composition and structure have been of relatively small importance in determining the relief in its major aspects. The chief exceptions to this are the two main cordilleras: the Western, where the surface features conform closely to the rock structure of the young volcanoes and lava flows, and the Cordillera Real where a hard granitic core amongst the folded shales and sandstones has preserved the crest of this range from the fate of the surrounding country.

But the composition and structure of the crust have an important bearing upon the most fruitful source of wealth to the country—its minerals. The granitic core of the Eastern Cordillera, as well as some of its shales, appear to be streaked with threads of gold too small to be economically worked *in situ* but yielding sure returns to the placer miners in the gravel deposits of the valleys; and innumerable fissures have become filled with rich ores of silver, tin, antimony, and bismuth. The crumpled sandstones and other sediments of the Altiplano have been broken along a line running northwest-southeast by an intrusion of diorite, which appears at the surface today in chains of low hills; and with this intrusion is associated one of the largest known deposits of native copper.

The volcanic activity in piling up the summits of the Western Cordillera has brought to the surface quantities of native sulphur, while the association of volcanic vents and lakes has resulted in the formation of borax in a number of intermont basins, and perhaps a somewhat similar cause will ultimately be held to account for the nitrates of the western piedmont. Both of these soluble compounds owe their preservation to the intense dryness of the climate of the region in which they occur. The existence of the interior basin in the highlands and its relative aridity account for the immense deposits of salt which cover its lowest expanses.

The map area lies to the north of the Tropic of Capricorn; and if it were a flat lowland its temperature, humidity, wind, and rainfall conditions would vary directly and uniformly with the apparent movement of the sun. The thermal equator and the

equatorial rains would follow the sun and pass over the area twice annually, moving southward in the end of November and again northward early in January. And during all but the height of summer the southeast trade winds would blow over the land. This theoretical condition is greatly modified however by the shape of South America and by the existence of the Andes. Owing to the relative narrowness of the continent in these latitudes, to the height and width of the Andes, and to the nearness of the Pacific Ocean with a cold coastal current, neither the thermal equator nor the equatorial rains ever reach the area, and the trade winds do not blow with their accustomed regularity. Still, the hottest period of the year for all parts of the area is between November and January, the coldest is in June or July, and the rainy season is from November to March. Probably the ultimate origin of most of the moisture, save on the Pacific slope, is the Atlantic Ocean; and the bulk of the precipitation is from the trade winds, as they are forced up the eastern flanks of the Andes, so that the only really wet part of the area is its northeastern corner.

The main climatic characteristics of the highlands are low precipitation and a great daily range of temperature, the thin air and high percentage of clear days promoting rapid heating by day and cooling by night. These highlands are classed among the semideserts of the world. The prevailing winds on the coast are south or southwest—more or less from the ocean, but in view of the high temperature inland they bring but little rain. The most they are able to provide as a palliative to the hot desert climate of the lowlands is a prevalent fog bank on the seaward slope of the coastal hills.

We shall see that the geological history of the Central Andes has a good deal to do with the nature of the existing flora and fauna, that is to say with the reason for the presence of certain species and the absence of others. But the present climatic division of the land accounts sufficiently for the zonal arrangement of the *vegetation*, while the more detailed distribution within the zones is determined in part by the soil and water supply. The

hot wet zone of the northeastern flank is occupied by dense tropical forest, most luxuriant at the foot, becoming less so upwards to the cold tree line at about 3,500 meters. Physiologic dryness which stunts vegetation may be effected by cold or simply by absence of water. This eastern tree line is determined by the first and probably also by wind. In the huge expanse of the high plateaus trees other than occasional plantations are extremely rare. It is the Puna country, covered naturally by low shrubs, mosses, and bunch grass but totally bare of vegetation where the soil is intensely salt. In the main the humble nature of the vegetation is accounted for by a combination of low temperature, wind, and absence of sufficient water. Superficially there is little change in the character of the vegetation down the western flank of the Andes, but closer examination shows that here the poverty is due more to real absence of water. The western foot of the Cordillera is marked by transition in most parts to complete desert, which continues over the lowland to the coastal hills and is broken only by the verdure bordering the sparse streams—permanent and intermittent. The coastal hills, or Lomas ("backs"), with their mantle of fog and occasional rains, support a winter vegetation of grasses and shrubs.

The Andean highlands have been occupied for an unknown period by a sedentary Indian population engaged primarily in agriculture but dependent also on the more ancient pastoral pursuits of their less settled ancestors; while, as culture progressed from the settlement onwards, the Indians gradually gained a knowledge of mining and metal working. In this, as in their methods of agriculture and standard of living, they had already reached a relatively high level under the despotism of the Incas before the coming of the Spanish conquerors in the sixteenth century. But this culture was restricted to the plateaus and to the few spots on the coastal lowland where irrigation was possible. The Quichua and Aymará tribes to which these Indians belong do not extend far down to the forested valleys and lowlands of the northeast, which are sparsely peopled by the much more primitive groups of Amazonian Indians. Today

the total population of the area is about 828,000 or 3.6 per square kilometer (9.3 per square mile); but it is by no means evenly distributed. It is densest in the lower parts of the plateau country such as the basins of Arequipa in the northwest and Cochabamba in the east, where low temperatures are infrequent and where irrigation can be practiced on good soil. In the upper parts of the eastern valleys and in the mining districts all of the most valuable agricultural land is held by the descendants of the Spanish *conquistadores* who represent but a small proportion of the total population, the estates being worked by the peon labor of the Indians. Some agricultural land is still held by Indian communities, but this for the most part is in the less favorable localities.

In view of the physical conditions briefly set forth above it is easy to understand that the map area is divisible into well marked natural regions and that these consist of a number of parallel belts following the general trend of the Andes from northwest to southeast (see Fig. 5). It will be useful to summarize at this stage the salient impressions of a traveler who follows each of these zones through their entire length in this area and to note the outstanding changes he would observe in passing from one region to the other.

From the deck of a vessel coasting along the almost harborless Pacific seaboard the observer is struck with the inhospitable appearance of the coast. A recent upheaval of the land has left everywhere a wave-cut terrace ranging in width from several kilometers in the north to a few meters in the south. Behind this rise the Lomas, or coastal hills, with numerous deep ravines and sparse verdure, to be seen only in winter. The aspect south of Arica is exceptionally forbidding (see Fig. 1). The coast is bold and precipitous broken only by the few deep gashes of the streams many of which carry no water for years at a stretch. The coastal escarpment, with an average height of 700 meters and rising in places over 1,000 meters, while maintained by the attack of the waves, can scarcely be due primarily to this. It is probably a modified fault plane which marks the break be-

FIG. 1—Pisagua from the roadstead. The town is built for the most part upon a raised beach. The cliff behind it is here over 700 meters high.

tween an old land and the Pacific abyss. Apart from the canyon mouths the coast is low only in two short sections, in the alluvial flat at the mouth of the Tambo and near Arica. On the Pampa of Tambo there is sufficient water to support a number of villages and farms. But elsewhere agricultural activities are restricted to isolated farms at wide intervals. Otherwise population is clustered in the ports, mere roadsteads with little shelter but each at the end of a railway. Three of them—Arica, Pisagua, and Caleta Buena—are of great importance to the interior, the first as the terminus of the most direct railroad to the Altiplano, and the others—crowded on to a narrow shelf at the foot of very steep slopes with local precipices—from their export of nitrates. These are mined on the Pampa behind and brought by rail over the rugged Lomas and, in the case of Caleta Buena, lowered down the 800 meters of cliff by a cable way.

Between the Lomas and the Andes lies the long belt of desert, to which is given locally the name "Pampa." But it is a very different pampa from the huge grassy plains of central Argentina. It is part of a continuous strip of desert extending from central Chile to a point some 80 miles beyond the western edge of the map area and continuing in patches to the northern limit of Peru. For the most part it is absolute desert and, except for widely separated river beds, is never better than semidesert with an exceedingly sparse cover of drought-resisting grasses. This piedmont surface between the *quebradas* is smooth or rolling, and rises slowly to east and northeast. Its soil varies from fine sand to coarse and angular rock fragments, the former being more characteristic of the lower and the latter of the higher parts. The surface layers are impregnated with salts to a greater or less degree. In most parts the lomas' crest is higher than the lower edge of the piedmont and overlooks it; but in places, such as north of Pisagua, there is a steady descent from the foot of the Andes to the cliff tops on the coast. The desert surface is roughened here and there by low hills which appear to be recent lava flows that have issued in general from local vents. Where the surface deposits contain much sand this is

blown by the prevailing southerly wind and built into crescentic moving dunes. Throughout the whole stretch the cordillera forms the distant horizon; and it frequently presents a strikingly smooth edge—generally the line along which the uplifted peneplane has been warped up to form the highlands, but often the summit of a great mass of accumulated lava flows that obscure the older and rougher topography. In such places only the summit of the highest volcanoes, which stand farther back, appear to break the monotony of the crest line. In other places, as northeast of Arica, peaks like Tacora and Taapacá rise upon the western brink of the high plateau. The traveler through the desert zone finds few evidences of life of any sort. For long stretches between valleys there is no water. But where the valleys carry streams which permanently reach the piedmont there are thinly peopled settlements along their banks, each with its small fields of alfalfa or vegetables making the most of the shade provided by plantations of willow and *chañar* trees. Two such settlements near the lower limit of abundant water are the towns of Moquegua and Tacna, each lying beside a wide alluvial valley. These are veritable oases, and their importance as market towns serving many valleys above them is marked by their connection by rail with the ports of Ilo and Arica respectively. But by far the largest population of the zone is found in the nitrate fields of the south. These lie in complete desert, unlovely groups of barracks, vats, and railroad sidings dumped on the sun-baked pampa around the flat *salars*. The climate has allowed the nitrates to form and remain, and the workers in this surprising hive of industry have to put up with the climate while nearly all their food is brought to them from outside, and all of their most precious water has either to be pumped from wells carefully placed and sunk so as to be untainted by the salts or piped from distant springs and streams in the piedmont.

The Western, or Maritime, Cordillera forms a belt within our area of 575 kilometers (some 360 miles) in length and is rarely much less than 125 kilometers (some 80 miles) in width, if we take the 1,500-meter contour as its foot. The landscape

in this belt includes elements of great regularity which cannot be lost sight of—the smoothness of the western flank which is the warped portion of the peneplane above mentioned, the strong "family likeness" which all the steep-walled ravines and gorges incised on this flank bear to one another, and so on. But it is the supreme irregularity of the peaks together with their barren grandeur which most impresses the traveler. The belt of summits is no system of parallel ridges and valleys which may be looked for in most of the world's great mountain chains. Rather does it resemble some gigantic breastwork hurriedly built of any materials which came to hand, the large and the small mixed indiscriminately. The atmospheric elements of denudation can be trusted to work to a plan; so can most of the great mountain-building forces. But we are here reminded that geologists have no basis for forecasting the nature and the scale of the outpourings of volcanism. For all of these peaks are volcanoes old or new, and within the limits of their zone they seem to conform to no plan of distribution. Large and small mountains stand side by side, and if they stood upon a low plain instead of on the brink of a high plateau they would scarcely merit the name of cordillera. Again, while all are "volcanic" peaks we must not suppose that they are necessarily symmetrical cones surmounted by craters. Many have this form indeed, such as El Misti, Tacora, and Sajama; but these are the youngest. The older members of the family have more or less lost their original shape under the influence of erosion. But, speaking generally, the slopes in the Western Cordillera are more or less the original slopes of deposit, whether of the lava flows or of the agglomerates and ash beds which have fallen round some center of eruption (see Fig. 36, page 167).

So much for the form of the landscape. The other important element—color—is supplied not so much by the vegetation, as in more humid districts, but by the rocks themselves. These are painted again and again in the most vivid tints and with the finest mineral pigments from the purples and reds and pinks of the lavas to the pure yellow of the sulphur; two important

elements are the gleaming white of salt or borax crusts, which frequently fill the hollows, and the snows on the peaks themselves.

The Cordillera is not a desert like the piedmont. The western flank and the lower slopes of many of the volcanoes themselves are clothed, although the cover is rarely complete. The traveler climbing from the west passes through a thirsty scrub dotted about with cacti of the candelabrum and pillar variety, which here and there close up to form a low cactus forest. Higher up the vegetation is also limited to scrub, but this time of *tola* and *yareta* with stretches of a pampa grass, and in many of the high valleys are grassy swards. A journey from end to end of this Cordillera is perfectly feasible, but it would be slow and would follow a very sinuous trail, and it is safe to say that no man has ever made it. Nowhere would animals be far from pasture or water. Groups of Indian habitations, all of the humblest variety, lie in nooks and corners everywhere throughout the entire range. The Indians are mainly occupied with the growing of crops, especially of potatoes and *quinoa*, sufficient for their sustenance. But they are also the owners of llama herds which they hire for the transport of ore and merchandise. Here and there they gather sulphur and borax and salt; and this, together with fuel consisting of scrub and llama dung, they carry on the backs of the llamas to the piedmont villages of the lowland. Thus they are able to satisfy the balance of their modest requirements.

The major part of the Altiplano falls within the map area, but it extends beyond the limits for some 200 kilometers to the northwest and 300 kilometers to the south. Its eastern edge is well defined by the sharp rise and straight front of the Eastern Cordillera; but the western margin is less clearly cut for the reason aforementioned, that the volcanic débris has encroached upon it and forms hilly districts of irregular outline. Moreover, in the south the plateau is divided into two basins of interior drainage by a line of volcanoes and hills extending from the Western nearly to the Eastern Cordillera.

Little is known of the country west of Lake Titicaca, but it seems probable that it consists of a plateau so much dissected by

FIG. 2—Part of the Altiplano looking southwest across the Río Desaguadero near Nazacara Gently undulating country with many low, mature ridges. The vegetation consists here of a sparse cover of *ichu* grass.

valleys as to have the appearance of a mountainous region. It probably is a part of the raised peneplane on which the volcanoes have been built farther west. In any case it is distinct in character from the Altiplano, which is lower and smoother, so that almost the entire width of the interior basin is here occupied by the waters of the lake. The Altiplano differs from most of the interior basins of the world in that it possesses a large, deep lake of fresh water—Titicaca—and an important permanent river drainage—the Desaguadero (see Fig. 2). This is accounted for by the existence of a deep tectonic depression to hold the water in close proximity to a high mountain range to windward which keeps it supplied with water. Southwards the Altiplano becomes more and more typical of other interior semideserts; for the windward mountains become lower, so that they condense less moisture. They also quickly become immensely broader, so that the precipitation is more widely distributed. But most important of all is the fact, in part accounted for by these conditions, that south of Titicaca all important streams flow eastward from the drier Western Cordillera and not from the Eastern Cordillera, which receives the heavy rainfall. Thus it is not surprising to find that the Desaguadero, with but one affluent of importance—the Mauri—and an aridity increasing southward, grows smaller downstream and feeds only a shallow water body—Lake Poopó. From this there is only a small outflow to a salt lake or swamp—Coipasa—on the fringe of the huge expanse of salt crust almost permanently dry. South of the volcanic barrier which separates the salars of Coipasa and Uyuni there are no fresh-water lakes and no permanent streams on the plateau.

The traveler in the course of a journey over the Altiplano from Titicaca southward is struck by a monotony of landscape almost as complete as in the case of the piedmont desert of the Pacific slope. It is true that in the south there are the lines of barren volcanic cones and at their foot the huge flat salars which have their own glistening monotony, and again there is the wide sheet of Poopó with its marshy rim. But save for these one bit of the

immense plateau is like another. It is a rolling plain, almost bare of trees and in many parts bare even of scrub. But more generally it is covered with *tola* and *yareta* bushes, coarse grass, and other humble plants. It is swept by winds and often by dust storms. The higher swellings of the plain are the rough edges of the harder rocks which have withstood the attacks of erosion; and these are frequently kept bare of soil by the wind. Much of the soil of the lower parts is impregnated with salt. It is primarily a pastoral country, and large droves of llamas and sheep with occasional flocks of alpacas give the chief touch of life to the scene; or the long strings of llamas and donkeys laden with ore, fuel, or merchandise, resembling the camel caravans of Africa or Asia. But the owners of the llamas are also farmers in a small way. Villages, or rather groups of huts, may be found in almost any sheltered spot where the soil may be tilled; and there will be the potato, oca, and quinoa patches of the Indians with perhaps *haba* beans and a little barley raised for straw. There are many signs of early mining operations all over the plateau; but two centers now eclipse all others in importance, Corocoro in the middle of the Altiplano and Oruro at its eastern edge. Apart from Oruro this margin has many groups of relatively dense population each occupying a small area of irrigable land at the mountain foot.

Near Titicaca the scene changes. Steep slopes approach the lake and alternate sharply with carefully tilled patches of good land, while even the slopes where not too rocky are terraced and cultivated (see Fig. 3). Villages with trees and churches are near together, and the traveler has the feeling of being in an inhabited country. The hilly peninsulas—Copacabana and Huata—thrust forward and almost sever the lower lake from the main depression of Titicaca. The connecting strait is flanked by steep precipices. The scene is one of great beauty and wants only woods to make it rival the charm of the Italian lakes. For all the other elements are there, the islands, the steep terraced slopes, the rugged rocks, and the villages clustering picturesquely in nooks and hollows. Moreover, there is the alpine background,

FIG. 3—Source of the Río Desaguadero, outlet of Lake Titicaca. The valley here cuts through the western end of the Cerro de Quimsachata (compare Fig. 39). The twin villages of Desaguadero, in Bolivia (left) and Peru (right) are seen on either side of the river which is shown receding into the right background.

for the great chain of the Cordillera Real rears its gleaming summits with cloud banners and hanging glaciers against a sky which is nearly always blue.

The northern end of the Altiplano was the cradle of an ancient civilization which has left as its only evidence wonderful megalithic structures, the ruins of its temples and dwellings. Lake Titicaca and its neighborhood again was one of the chief centers of the later Inca civilization. Today, as then, the shores of Titicaca are more densely peopled than most other parts of Bolivia, while the situation of La Paz near by marks it as the real heart of the Republic, although close to its western frontier.

East of Titicaca the plateau rises gently over a piedmont to the foot of the Cordillera Real. But for the traveler who makes his way by road or rail eastward from the lake's outlet by the valley of the Río de Tiahuanaco a surprise is in store. He has barely reached the rising piedmont when he finds himself on the brink of a wide chasm separating him from the mountain front. This is the valley of the La Paz River, and the city of La Paz is spread over its floor and lower slopes six hundred meters beneath him. He may follow this canyon lip southeastward for nearly forty miles (60 km.) with the river bed deepening all the way (see Fig. 4), and then he must continue for nearly fifty miles more around the southern ramifications of the La Paz valley before he can start the ascent of the Cordillera. This great slice has been cut from the Altiplano by the La Paz River which is a head stream of one of the great tributaries of the Amazon, the Río Madeira. So great is the erosive power of water fed by continuous condensation on the windward slope of the Andes that the Amazon has been able to break the resistance of one of the most powerful bulwarks of the Cordillera and so to begin the attack upon the interior basin of the Altiplano. The scale and grandeur of this evidence of power cannot fail to impress the man who stands for the first time on the Alto of La Paz and sees below him a world apart. We shall see, however, that in spite of its apparent separation from the world above the inhabitants of La Paz valley cling to the links which bind them

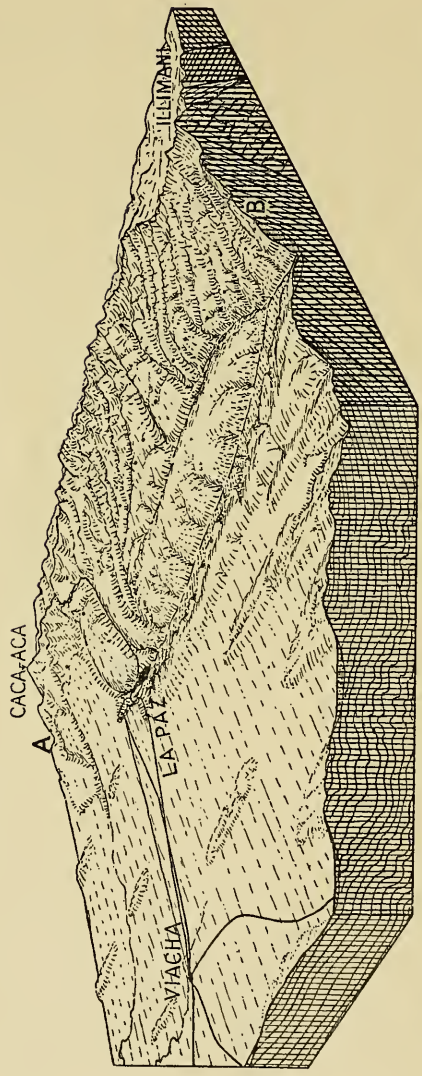


FIG. 4—Block diagram of part of the Cordillera Real and Altiplano with the La Paz valley, viewed from the south. Extreme eastern limit of the detrital "La Paz" deposits is indicated by the line of dots A-B.

to the Altiplano with its inhospitable climate and to the Pacific, and not to the soft and luxuriant world immediately below and the far distant Atlantic. The explanation of this lies in the fact that the people came from the plateau, as well as in the nature of the Cordillera and the plains to the east of them.

The Eastern Cordillera in the area of the map falls into two quite different divisions, a northern section where it is relatively narrow and a southern where it is wide. The inner margin of the northern section runs from northwest to southeast while that of the southern is oriented nearly north-south. In the north the map includes practically a complete cross section of the Cordillera; but south of latitude 17° barely one quarter is included. The consequences of this division are many and important. The original character of an uplifted peneplane has been almost completely destroyed in the north, for the concentration of the rainfall in a narrow belt and the relatively steep gradient of the initial rivers have combined to enable these streams to cut the old surface to pieces. Moreover, the Cordillera Real even at the time when the peneplane surface had been developed elsewhere remained as a high range of hills above it.

In the more southerly division perhaps the most striking feature is the general accordance of level of the summits and the complete absence of important peaks above the general summit level. At the highest altitudes, then, the old peneplane is in evidence, though by far the greatest part of the surface is hilly. The slopes are gentle and the valleys wide. This surface seems to have been formed by a long period of erosion after the peneplane had been raised but long before it was pushed up to its present level. In places, as about Cochabamba, the surface has been warped or faulted down and the hollows are now filled with detritus, providing a rich soil which is occupied by the densest agricultural population in Bolivia. The process of rapid dissection, which has gone so far since the great Andean uplift in the northern part of the Eastern Cordillera, has affected the southern division only on its outer edge—in the northeastern corner of the sheet—and where the main head streams of great

rivers such as the Grande and Pilcomayo have cut their beds in narrow gorges; and even these have barely touched the area included in the map.

Thus the two mountain areas are strongly contrasted in their form, the northern being a region of tremendous declivities, sharp spurs, and swift rivers, while the southern consists almost entirely of wide hilly plateaus and graded rivers. Furthermore, there is a great difference of climate, already alluded to, the north receiving almost daily rain—or snow near the summit—the valleys constantly humid and lying for much of every day under great rolling clouds. In the south rainfall is much lighter, and save on the outer edge there are no hot and humid valleys. The valleys and basins of this section have perhaps the most delightful climate in South America. It is that of almost perpetual spring. All the products of temperate lands and many of the fruits of the tropical lowlands will grow there. Moreover, there is much good pasture on the valley slopes. But on the higher parts conditions are even more rigorous than on the Altiplano. A humble scrubby vegetation and sparse Indian settlements hugging the sheltered hollows in general are the signs of life on this hilly upland. But there remain the mines. Colquechaca, Uncia, and Huanuni are three of the most important centers of tin-mining in the world.

The La Paz River makes its break in the Cordillera Real in an immense gorge over twelve miles (20 km.) across in an air line from peak to peak and 3,500 meters deep, its slopes being exceedingly steep in the lower part and more gentle above. North and south of this gorge the range has been heavily glaciated and in all respects is thoroughly alpine in character. Snow-clad peaks and sharp *arêtes* rise from rounded cirques and lake-studded, troughlike valleys, in many of which small glaciers still remain. Mines of gold and silver and tin are worked at a number of points along the slopes even up to the snow line, and for every mine now open there are remains of many others; while scattered Indians cultivate their patches in most inhospitable spots even close to the snows.

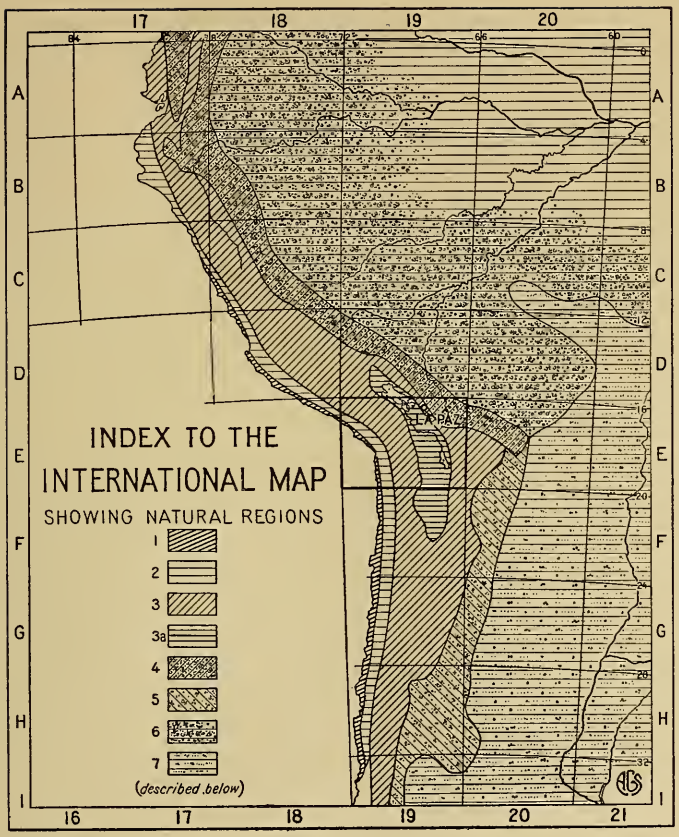


FIG. 5—Natural regions of the Central Andes.

1. Coastal hills with moisture and vegetation in winter.
2. Desert piedmont with oases in some of the valleys.
3. The Puna: high, dry cordillera with intermont basins in the south, unforested.
3a. The Altiplano: an intermont basin with "Puna" characteristics.
4. Broken mountain slopes, moist and forested.
5. Broken plateaus and intermont basins with scrub and some woodland.
6. Plains, hot, moist, and mostly forested.
7. Plains, with cover of bush, grass, and scrub, gradually changing from north to south.

From these summits the eastward descent leads to another world with astonishing abruptness. Yungas, as the region formed by these eastern slopes is called, is characterized by its intricate topography (see Figs. 29 and 37), its warm, humid climate, becoming hotter with every foot of descent, its dense forest of varied trees and impenetrable undergrowth, and its rich fauna. All products which require heat and moisture will grow there, and the only obstacles to its development as one of the world's leading areas of tropical agriculture are its inaccessibility and its lack of level spaces. As it is, however, there are many narrow river flats where sugar cane and tropical fruits are intensively cultivated. Moreover, its most valuable products are coffee and coca, which are suited to cultivation in terraces and require a considerable rainfall and warmth without too much sun.

The villages for the most part lie near the valley floors, or else on spurs which are of sufficient width, but always where the country permits of trails to connect them with other villages and ultimately with the Altiplano. For the plateau is their market; and even this district, so difficult of access from the west, looks up rather than down. Its connections with the Amazonian plains have yet to be made. The Indians of Yungas are still mainly of Aymará stock, which means that they hail from the plateaus. The limit of civilization and of economic life falls near the foot of the Andes and just touches the corner of our area. We have here reached the low sandstone ridges which form the outworks of the great Cordillera. A mantle of high tropical rain forest covers the land. It is unpenetrated save by the savage tribes which live along the rivers and by a very few missionaries and planters. Their numbers as well as their wants are small. The inhabitants of one valley have little intercourse with their neighbors on the next, and indeed they often speak different languages.

CHAPTER II

GEOLOGICAL STRUCTURE AND LAND FORMS

The median line of the southern Andes from 18° S. to 56° S. approximates very closely to a meridian. Within the areal limits of the La Paz sheet this line swings abruptly to a northwesterly direction, and the cordillera enters upon the great curve to the west which gives the northern Andes (from 18° S. to 10° N.) a nearly semicircular trend. The largest of the physical features in the area reflect this important change in direction. Thus in the northern half the coast line and the two chief cordilleras have the northwest-southeast trend, and rivers in the main follow this trend or run perpendicularly to it. In the southern half of the coast line, the Western Cordillera and the western edge of the Eastern Cordillera trend almost north and south. But each of the tectonic forces which have affected the crust in this area has left its marks throughout both sections. Thus in the northern we find an important line of summits west of Titicaca which trends from north to south and continues the coastal direction south of Arica. And again the parallel line of escarpment east of Lake Poopó is continued northward through the cordillera by a furrow of lower land, the basin of the Ayopaya River. Moreover, in the southern half the meridional direction is not coincident with the strike of the folded rocks. For the folds, in so far as the volcanic rocks allow us to see them, follow the same direction as they do in the northern part—northwest-southeast—a direction which has been taken by the headstreams of the Grande and Pilcomayo rivers.

The most outstanding contrast between the Andes immediately north and south of the La Paz area is their much greater width to the south. This increase in width is abrupt; and it takes place about latitude 17°, or approximately the position of the bend in the cordillera and coast. It is natural to seek for surface

features about this line of change which may be connected with the tectonic conditions which account for it. If we draw a straight line from the coastal bend at Arica to the point of bending on the inner face of the eastern Cordillera just north of Oruro, we find this line passing through the two highest volcanic peaks in the area—Payachata and Sajama, the cone of the latter standing out to the east of the main cordillera; while beyond these the line traverses a swelling which forms a minor water parting on the Altiplano. Moreover, its continuation in the Eastern Cordillera coincides with the divide between the basins of the Río Grande and Río Beni systems; while still farther to the east it forms the axis of the basin of Cochabamba, which has been recognized as a region of crustal weakness and hence of subsidence. Thus there is strong superficial evidence of the existence of an important tectonic feature running east-northeastward from the Pacific at Arica. Beyond the map area in this direction the topography is not well known, but it is probably significant that the line if prolonged would reach the Amazonian plains under 100 kilometers; while a line drawn due east from Arica and produced beyond the area would leave the Cordillera at a point nearly 280 kilometers to the east.

It is noteworthy that the Poopó-Coipasa basin on the Altiplano is divided from that of Uyuni by a range of hills—volcanic in its western part—which trends east-northeastward. This would seem to indicate a second line of crustal weakness following this direction and some 200 kilometers distant from the first.

Geological knowledge of the area is not sufficient to permit the compilation of a complete map. Investigations have been made over a number of routes—by Orbigny, Castelnau, Pissis, Forbes, Steinmann, Sundt, Dereims, J. A. Douglas, H. E. Gregory, Block, Rogers, Kozlowski, Washburn, and others. Of these geologists Orbigny and Forbes made geological maps of the whole region. But neither of these can now be accepted as accurate. In addition to this, much detailed work has been done in the limited areas of the mines, and the Bolivian Government has published maps of each department showing areas

which are supposed to yield the various minerals. These maps also show the distribution of hot springs, which throws some light upon the situation of geological faults.

The physiography of the area has been studied by Bowman, who has been able to compare it with that of the adjoining regions to north and south. The glaciation features of the Eastern Cordillera have been examined by Hauthal and later by Sefve. Several special physical features have been examined scientifically, amongst them the hydrographic system of the lakes on the Altiplano by Neveu-Lemaire of the Créqui-Montfort expedition, the La Paz gorge by Gregory, and the sand dunes of the Pampa de Islay by A. E. Douglass. The relation of the geology to the minerals as well as the mining activities of the area have been admirably summarized by Miller and Singewald after an inspection of all the more important mining localities, and they have also published a valuable bibliography of these subjects.[1]

While the total amount of geological knowledge is too incomplete to permit a general geological map to be drawn, it is possible with the help of the writings above mentioned and from observations made in other parts of the Andes to arrive at a fairly reasonable account of the physical history of the region from Silurian to Cretaceous.[2] For our present purpose it is unnecessary to go into this; but without some conception of the region as it must have appeared about the middle of the Tertiary it is impossible to understand the present physical features of the Andes.

Sedimentary rocks of nearly all geological ages and of very varied character occur in the region, and all alike are folded with a northwest-southeast strike. The general arrangement and posture of the rocks in the northern half may be studied in the four cross sections of Forbes[3] and of J. A. Douglas[4] although these two authors differ considerably in their interpretations. Similar sections have been made in the southern part by A. P.

[1] References to the published writings of the geologists above mentioned are given in Appendix C, Bibliography.

[2] The structure and paleogeography of the Central Andes is discussed by Guido Bonarelli in a recent paper (59).

[3] David Forbes, (57). [4] James Archibald Douglas, (61, 62).

Rogers and Washburn, but these remain unpublished. It is clear that the present high Andes had an ancestor, probably of much lower elevation, which owed its origin in the main to the crumpling of the rocks above mentioned. There is ample evidence of the later destruction of this range by denudation. The various folded strata of the Altiplano, which is the part least disturbed by later erosive agencies, remain truncated and worn almost to a plain—now greatly elevated, and the general accordance of summit level in the Eastern Cordillera south of latitude 17° bears further witness of this. The Cordillera Real was apparently a residual mountain area, but the smooth slopes of the present Western Cordillera have been recognized by Bowman[5], where he studied them just south of the map limit, as a warped peneplane surface. It may be further surmised with reason that an old erosion surface, if not a peneplane, extended out over the edge of the present Pacific Ocean.

That a moderate uplift of the peneplane in our area followed is evidenced by the dissected nature of the peneplane surface and especially on the eastern side of the range. That the uplift was slow or that a long period elapsed after this moderate elevation is clear from the fact that the dissected surfaces of the Eastern Cordillera are mature. This uplift was probably accompanied by a sagging in the middle—as if it were the keystone of an arch—in that the Altiplano has remained protected from this mature erosion. The sagging was probably accomplished at least in part by faulting. Any fractures at the western border are of course concealed by volcanic rocks, but the eastern margin of the Altiplano south of Oruro is a dissected fault scarp truncating the strike of the rocks and having hot springs at its foot. Moreover, at least two important faults have been mapped, at Corocoro and at Coniri, 45 kilometers north-northeast of that place. The Strait of Tiquina apparently coincides with a fault line, and the form of the submerged slopes of Lake Titicaca and the rectangular shape of its basin led Gregory[6] with reason to describe this as a warped and down-faulted section of the crust. In the

[5] Isaiah Bowman, (74). [6] Herbert E. Gregory, (76).

Eastern Cordillera two important faults with their downthrow to the east have been recognized by Block[7] at the crest of the mountains northeast of La Paz; and it is most probable that the straight edge of the hills bounding the subsidence basin of Cochabamba on the north is a fault scarp.

The earlier elevation of the Andes—the first which has exercised direct influence upon the relief of the Andes of today—went on through Tertiary time, and it had the further accompaniment of vast volcanic activity in the western part and igneous intrusions in the east. Amongst the intrusions we may include the porphyrite boss which forms a hill group on the southwestern side of Lake Titicaca, the diorite which accounts for the Cerro de Comanchi north of Corocoro and probably other hills in its neighborhood, the igneous mass of the hills of Oruro—which bears its ores, and a number of separate intrusive sills on the Altiplano west of Oruro described by Orbigny as of trachite. All of these form isolated hills to roughen the surface of the Altiplano.

Beyond the escarpment of the Eastern Cordillera the plateaus about the Cerro de Morococalla are composed for several hundred square miles of andesite, which appears to have overflowed a surface already dissected to maturity and must therefore be regarded as one of the most recent intrusions. Lastly we must mention the granite which crops out in the Cordillera Real both in its summits and to the east of them. The injection of this rock may, however, be much older than all the others mentioned above.

From these brief indications some idea will be gained of the extent to which the land forms of this part of the Andes owe their origin to the processes of mountain building and crustal fracture anterior to the greatest uplift of the Cordillera. We have to look back to a picture in the mid-Tertiary of a belt of upland much lower than the present Andes but having already many of the existing surface features. And without this portrait of the earlier form the significance of the present mountain

[7] Henry Block, (66).

surfaces cannot be appreciated. Thus the folding of the rocks to their present postures had already been accomplished, and most if not all of the igneous injections in the eastern part had taken place. The surface of the folded rocks, which long before had been reduced to a peneplane save in the Cordillera Real, had again been etched to a mature relief in most parts; the chief exception being the Altiplano, which had by this time sagged down to its present relative position. Already the volcanoes had begun to pile up in the western part of the area. It cannot be stated with any certainty that the Pacific waters had yet taken the place of a land area beyond the present coast line, or whether the subsidence of this land took place in its entirety contemporaneously with the great uplift of the Andes.

This lower Andean land must have offered a much less serious barrier to the mobile elements—atmospheric, vegetable, and animal; and the intensification of contrasts of climate, vegetation, and fauna which now exist in the region must have been brought about gradually throughout the progressive uplift of the Andes after this stage. The present constitution of the flora and fauna can be understood only by taking into account this condition which prevailed prior to the upthrust of the great land mass; and the existing climatic belts are manifestly the result of the great differences in altitude of land lying athwart the normal currents of air circulation.

After detailed study in a surveyed portion of Peru (73rd meridian) Bowman[8] has calculated that the recent uplift of the Andes in that section amounts to at least a mile (1,610 meters). In this uplift the entire Cordilleran belt seems to have behaved as a unit, although there were probably local warps and fractures which broke the uniformity of the surface of erosion along the line now followed by the Western Cordillera. The increased height is not the result of renewed crumpling of the rocks, and the uplifting force may be presumed to have acted vertically.

The further modification of the landscape in our area results in large measure from this rapid uplift. The change in form

[8] Isaiah Bowman, (8) Chap. 11.

effected by the elevation appears to be a warping of the surface along the western margin of the highland; on the eastern side, a tilting of the plateaus towards the east. Apart from the continued and perhaps increased volcanic outbursts in the Western Cordillera most of the physical features which remain to be accounted for are due to the denudation processes acting on the high block from the time of its maximum elevation.

The rejuvenation of all the rivers save those draining to the central depression gave a fresh start to erosion in their valleys. On the eastern slopes the greater height of the cordillera occasioned increased rainfall and so added to the erosive power of the rivers there. On the other hand, the decreased humidity on the western slope somewhat neutralized the effect of uplift upon the activity of the streams or at least restricted rapid valley deepening to the beds of the larger streams. At the same time it initiated complete desert conditions on the coastal highland and gave effective play to the mechanical disintegration of rock and to the eroding and transporting power of the wind. To a lesser extent similar characteristics developed on the Altiplano; but there the surface features were greatly modified by the distribution of water, of which more remains to be said. The elevation of the Andes brought their crests above the line of permanent snow where they still remain, the present limit being at about 5,000 meters. But the cold climate now characteristic of the higher parts of the region is warm as compared with the rigorous conditions which prevailed throughout the periods of Pleistocene glaciation. The long-drawn cold phases of this climatic episode caused the formation of snow fields and groups of glaciers on the mountains—widespread on the Eastern Cordillera, smaller on the volcanoes of the western range. There were certainly two and perhaps three such glacial epochs, and between the cold phases came an interval—or intervals—of mild climate. The glaciers radiating from the eastern snow fields reached to the piedmont on the rim of the Altiplano, on the one hand, and extended far down into the gorges of the Yungas, on the other. The ice tongues from Illimani and Tres Cruces met in the bottom

of the La Paz gorge during the last great extension of the ice, at the point where it cuts through the cordillera, and probably dammed back the waters of the upper valley to form a temporary lake. The glaciers which now lie in the fastnesses of the Cordillera Real and Quimsa Cruz are mere vestiges of these giants. But the ice caps have left their mark in profound modification of the mountains which nourished them. The summit of the cordillera is a succession of alpine pyramids connected by knife-edged ridges which are the limits of great ice-chiseled cirques and troughs. In the cordillera north of Cochabamba the ice cap found a different type of site for its work. Here the ice must have lain upon smooth plateaus creeping downward over their edges much as the ice fields of Norway do today. The valleys which notch the plateaus have been deeply modified by ice, but the high surfaces display as evidences of glaciation mainly the shallow lake-filled hollows and morainic litter of dying glaciers.

To appreciate the nature of the surface and underlying rocks on the Altiplano it is necessary to have some conception of the recent physical history of the plateau. We have seen that among the chief irregularities of surface in this long structural depression are its deepest hollow—the bed of Titicaca—and a shallower saucer to the south of latitude 18° S. The residual ridges on the plateau corresponding to the outcrops of stronger rocks—for the most part the folded sandstones with interbedded rhyolites in some of the western ridges and igneous intrusive rocks in places—follow the strike of these rocks. While more or less parallel, these ridges are neither continuous nor straight, and on account of the bends their directions vary between east-southeast and south-southeast (see Fig. 4). It is specially important to notice the course of the most easterly of the ridges. North of the Alto of La Paz this appears as a line of low discontinuous hills closely hugging the piedmont, but south of the Alto it forms an unbroken and widening rampart dividing the plateau from the La Paz gorge, while the next ridge lying *en échelon* performs the same function in regard to the valleys of the Ríos Sapahaqui and Luribay (see Fig. 4).

These ridges are the last outcrops of the folded sedimentary rocks of the Altiplano. They are superficially separated from the folded sediments (shales, quartzites, etc.) of the Cordillera Real by an apron of piedmont deposits north of La Paz, and south of that by immensely thick detrital beds—of gravel, sand, and clay with some intercalated tuff and lignite—in which the valleys of the La Paz, Luribay, and Sapahaqui Rivers have been incised to a depth, in the case of the first, of nearly 2,500 meters and have been carved into fantastic buttresses and pyramids.

Over large tracts of the Altiplano in its lower parts is a mantle of deposits which have been named the Puna beds. These lie horizontally on the truncated edges of the folded rocks of the peneplane. They consist of reddish and yellowish sands with irregular lenses of gravel and occasional marl and clay bands. The beds are coarser in character near the ridges and finer at a distance from them. They contain, at Ulloma and other places, the fossil remains of large mammals which required in life a luxuriant vegetation for their nourishment and presumably a milder climate. The Puna beds are believed to have been laid down in standing water probably of a lake or lakes, and in their waters the mammals must have perished. The elements of an important geological problem are provided by these features: the La Paz gorge and its moraines, the La Paz basin deposits, and the Puna beds with their mammalian remains. Controversial views have long been stated regarding each of them; and even now, while they can be recognized as elements of the same problem, no complete solution can be offered. Nevertheless since the unraveling of the latest stages in the physical history of the region with which these elements are so closely related must be based on the keenest examination of the existing surface features and probably upon accurate leveling which has still to be carried out, it will be useful to state briefly the views of those who have studied the question.

Philippi[9] believed that the animals whose remains are now

[9] A. R. Philippi: Vorläufige Nachricht über fossile Säugthierknochen von Ulloma, Bolivia, *Zeitschr. der Deutschen Geol. Gesell.*, Vol. 45, 1893, pp. 87–96.

found at 4,000 meters above the sea lived in a tropical lowland and that the elevation of the Puna region took place after their extermination. Sundt at first believed that the Puna beds were of marine origin and that their fossils were probably contemporaneous with those of the Argentine pampa, which necessitated an elevation of some 4,000 meters since the advent of man. In 1900[10] he renounced this view in favor of the opinion that the Puna beds were laid down in a huge Quaternary lake stretching from Lipez in southern Bolivia nearly to Cuzco in Peru, whose waters were dammed by glaciers; but he adds that since it is improbable that the mammals could have lived in the glacial climate it is possible that the beds are post-glacial and were deposited in lakes of reduced size. In 1902 Pompeckj made a careful examination of the Ulloma locality and stated his belief[11] that the Puna beds were formed after the elevation of the Andes. Sefve in a similar investigation in 1910, examines the whole question of origin[12] in considerable detail and in the light of previous researches. Beyond stating that the change in the hydrography of the plateau after its peneplanation was due to the filling up of valleys—probably on account of fluvioglacial agency—resulting in the formation of lakes, he reaches no very definite explanation of the presence in their deposits of mammals such as the mastodon; but he concludes that the critical point at which to find evidence regarding the damming of the drainage outlet is the La Paz valley.

Many geologists have studied the La Paz sedimentary deposits. Their results are briefly summarized by H. E. Gregory,[13] but he omits to mention the important observations of Hauthal made in 1908.[14] Gregory confines himself to a geological description of the strata, and while stating that they are deposits of low-grade piedmont streams with temporary lakes, he draws no conclusion

[10] Lorenzo Sundt, *Bol. Soc. Nacl. de Mineria*, Ser. 3, Santiago de Chile, 1900; also *Rev. Chilerra de Hist. y Geog.*, Vol. 36, 1920.
[11] J. P. Pompeckj, *Paleontographica*, Vol. 52, Stuttgart, 1905.
[12] Ivar Sefve, (77).
[13] Herbert E. Gregory, (76).
[14] Rudolf Hauthal, (73).

regarding their age or the regional significance of their formation. Hauthal regards them as of interglacial age, relying upon his discovery of glacial till below them at Ananta, while he, like other observers, found moraines resting upon them. Sefve, returning to his investigations in 1920, followed the La Paz valley to the Angostura gorge where the valley enters upon its northeastward trend through the Cordillera. In a provisional account[15] he states that he found no evidence of the La Paz valley above that point having been occupied by a glacier but is satisfied that immense ice streams from the Illimani group on the one hand and the Quimsa Cruz group on the other converged at the gorge of Angostura and that these were sufficient also to flood the Altiplano. Sefve further reports the recent discovery by Kozlowski that the materials resting upon the till found by Hauthal at Ananta are not the La Paz beds but are deposits formed by the river.[16] The La Paz beds, therefore, are probably preglacial. The complete geological history of the La Paz gorge remains to be written. Unfortunately the thick detrital deposits in which the existing valley is cut have furnished no fossils. If the deep and wide hollow in which they lie was carved by a river, it seems evident either that the latter was a large and powerful stream perhaps having its source in the present bed of Titicaca or beyond or else that an immense space of time was occupied in excavating the hollow. Equally clear is it that another long period elapsed in which this longitudinal furrow became filled to the level of the Altiplano by the La Paz deposits. If Gregory's view be the right one, it would seem that the deep furrow containing the deposits—whatever its origin—is a very old feature, probably an important feature of the older and lower precursor of the present high Andes. The period of deposit here would then correspond to the long period in which other surfaces attained maturity in their development; while the re-erosion of a deep valley in the deposits—the present gorge of the La Paz River—would correspond to the main uplift of the Andes. In addition to the detailed examination of the Puna beds at Ulloma

[15] Ivar Sefve, (75). [16] *Ibid.*

and vicinity, scattered observations on their distribution have been made by a number of scientists from Orbigny onwards. Of these J. B. Minchin probably had the widest knowledge of the Altiplano, and after numerous journeys made during his long residence in Bolivia he was able to construct a tentative map of what he called a former high-level lake now represented by shrunken fragments like Titicaca and Poopó. This map is represented in Figure 6 (A). It was sent to Dr. Bowman only a few weeks before Minchin's death and has not been published hitherto. But Minchin and many others based their interpretations upon notions that were much too simple. They assumed but one lake period whereas there were several. The precise level of each lake and its real extent will not become known until a detailed topographic survey has been made. It will then be revealed also to what extent deformations have occurred of shore lines and marginal and bottom deposits from the end of the lake period down to the present. Only an outline of the lake history can be given from the fragmentary information now available

It is theoretically sound to conclude that by the end of the period of greatest erosion lakes were probably absent from the Central Andean landscape. There followed a period of deformation, and great lakes were formed; and in respect to them and to other local and especially marginal base levels mature slopes were carved in a second erosion cycle whose effects are among the most prominent today. But all these changes took place at a much less elevation than the surface has today. Moreover, the deposits are of far greater age than those directly associated with the existing levels of lake basins.

When a second period of deformation set in with contemporaneous elevation a second opportunity was given for lakes to form; but whether or not they did form depended upon climatic conditions as well as relief. A high-lying series of calcareous deposits, old and weathered in appearance and fragmentary in occurrence, mark an earlier lake period; as the benched hills and spurs, fresh tufaceous deposits, and far more continuous

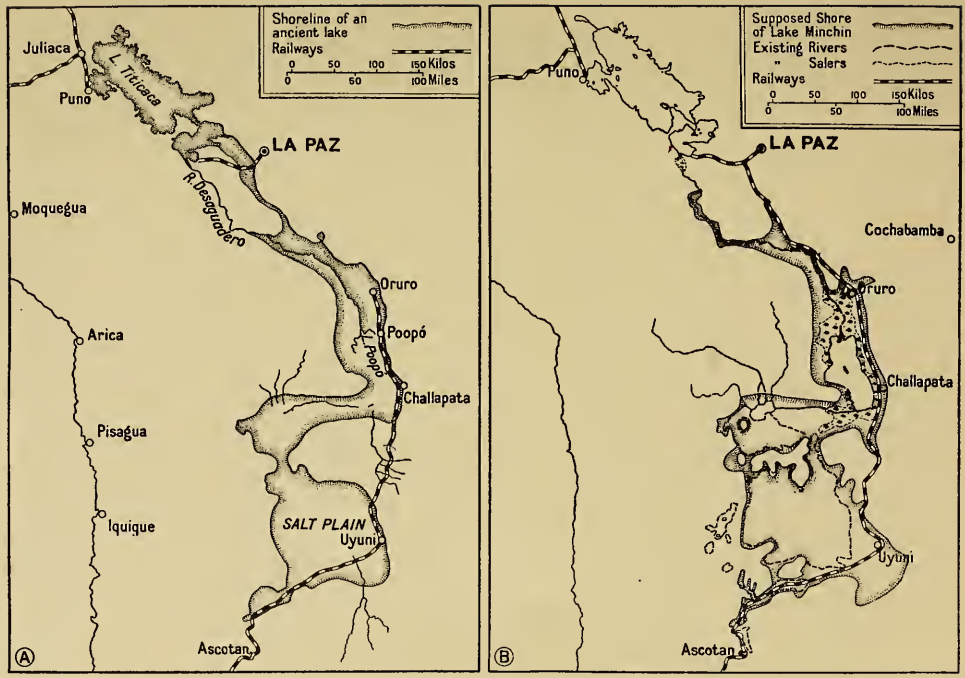


FIG. 6—(A) Sketch map of an ancient lake by J. B. Minchin (copied from the original in possession of the American Geographical Society); (B) Sketch map of Lake Minchin, the later and lower of the two high-level lakes of the Altiplano.

distribution of shore forms mark a later period of lake development. Each of these periods may be divisible into several phases, but of the existence of at least two main periods there can be little doubt. To the first and higher of these lakes Bowman has given the name Lake Ballivián, and to the second and lower, Lake Minchin.

In the second of the two periods the general position, level, and outlines of Lake Titicaca did not differ materially from their present condition. In Figure 6 (B) an attempt has been made to represent the probable outline of Lake Minchin. The level of the highest bench top at the Cerro de Oruro (with reference to the railroad) corresponds with the level of laminated near-shore clays and other deposits in the Desaguadero valley near Nazacara, six meters below even the present surface of Titicaca. Whatever extra water supply Titicaca may have had was compensated by increased discharge. On the contrary, the Poopó basin, without outlet, was all but filled up. Its northern arm was but six meters below Lake Titicaca. Had the climatic conditions been only a little more extreme an actual junction with Titicaca would have been made.

Whether the successive benches and calcareous shore deposits on the border of the Poopó basin mark stages in the lowering of the lake as a drier climate intervened or whether the former lake dried up altogether to come again into existence and rise to a lesser level than before, has not yet been determined. In any case, the whole series of changes ended with the almost complete drying up of the Poopó basin. Poopó itself and Coipasa are but shallow pans of extremely saline water bordered by wide marshes and salars. In 1914 Bowman gave an interpretation of the relations of the two main lakes to each other[17] and to their surroundings, and his diagram is reproduced herewith (Fig. 7).

The ancient Lake Minchin extended up the Desaguadero valley as far as Ulloma, and northward beyond it, and we may conclude tentatively that it was in this water body that the fossil remains were originally submerged. If the glacial dam in

[17] Isaiah Bowman, (75).

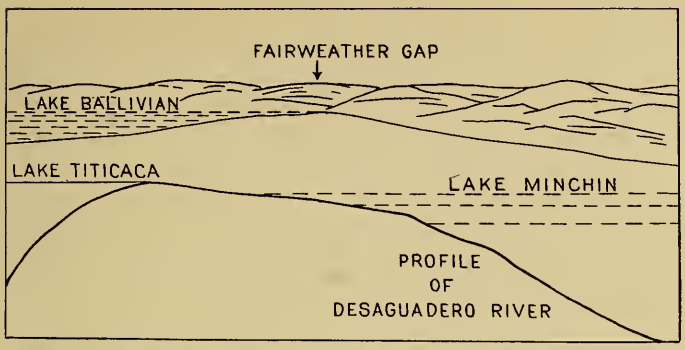


FIG. 7—Sketch showing relations of lake levels at Fairweather Gap, ten kilometers north of Calacoto. Lake Minchin, a temporary lake of glacial times, came into existence long after the Desguadero had cut down its valley from the level of Lake Ballivián to that of Titicaca.

the lower La Paz gorge was the agent which caused the impounding of the water, we may further conclude that this lake and its deposits are of Pleistocene age. In this connection we may note that in other sections of the Central Andes fossiliferous lacustrine deposits have been assigned with good reason—on geological and paleontological evidence—to the late Pliocene or early Pleistocene; for instance, the strata examined by Herbert E. Gregory and G. F. Eaton[18] in the Upper Apurimac basin. These beds near Ayusbamba lying at an altitude of about 3,800 meters—approximately the same as the Ulloma deposits—were found to contain remains representing the Camelidae, Equidae, Elephantidae, and Mylontidae.

THE DRAINAGE SYSTEMS

Recalling the outlines of the probable physical history of the Central Andes, we may discern interesting relations of the present drainage systems with the rock structure on the one hand and

[18] Herbert E. Gregory: Geologic Reconnaissance of the Ayusbamba (Peru) Fossil Beds, *Amer. Journ. of Sci.*, Ser. 4, Vol. 37, 1914, pp. 125–154; George F. Eaton: Vertebrate Fossils from Ayusbamba, Peru, *ibid.*, pp. 141–154.

the various surfaces of erosion and deposition on the other. The earlier and lower predecessor of the present high Andes presumably was originally drained in the first instance by consequent rivers running generally to the northeast and southwest. We do not know where the original divide of these ancient mountains lay; but it is worthy of note that the existing hollow in the Western Cordillera now followed by the Mauri River and by the railway is approximately west-southwest of the gorge of the La Paz River where it pierces the Cordillera Real. Owing to the volcanic nature of the Western Cordillera it is unlikely that any other similar valleys can be found; but it is possible that detailed surveys would reveal remnants of an ancient drainage system—possibly consequent—in the non-volcanic parts of the high plateaus west of Lake Titicaca and in the Eastern Cordillera south of the La Paz gorge.

The long period of erosion which supervened before the Andes were elevated to their present position and which sufficed to produce mature surfaces in most parts of the land undoubtedly brought into existence the type of valley which prevails today in the Eastern Cordillera and on the Altiplano—the "subsequent," or "strike," valleys, in which rivers have incised their courses in the weakest rocks and so follow the general direction of their strike—north-northwest to south-southeast. Such valleys are numerous in the basins of the Río Grande and Río Pilcomayo, as well as on the Altiplano. The present network of rivers, then, on the Altiplano and east of it probably conforms in general to the net which was already developed before the greatest uplift of the Andes. The chief effect which this uplift has had upon the rivers is the progressive and rapid deepening of their beds.

The Desaguadero is a "strike stream" from Titicaca at least down to Ulloma. Beyond this it may be occupying a slight structural depression. In the Cordillera west of Titicaca it looks as if the present divide were older than the line of volcanoes which stand upon the western brink of the high country. The Chili and Tambo Rivers have succeeded in maintaining a south-

westward course in spite of this volcanic barrier. Elsewhere in the Western Cordillera the rivers of the Pacific slope have their sources amongst the volcanoes. Their relatively straight courses are consequent in general upon the warped slopes which date from the great uplift. In detail they depend doubtless upon local conditions such as the form of lava flows.

The various agents of erosion and transportation act differently in the various parts of the area of the La Paz sheet. Mechanical disintegration of rocks plays a much greater part than chemical decomposition in the puna and the desert littoral. The intense insolation on the mountains and high plateaus followed by rapid radiation at night or when the sky becomes overcast causes a crumbling of the rocks which probably takes place at as rapid a rate as anywhere in the world. In the drier regions occasional rain storms quickly fill the dry quebradas, and the streams bring down quantities of rock fragments to the Altiplano or to the coastal desert, where they are added to the alluvial fans that mark the lower end of every gorge. Where streams are absent on the mountain slopes the downward creep of the fragments is less rapid but no less sure. The wind carries the sifting of the débris a stage further, rolling the lighter grains, lifting the lightest and building them into sand dunes. These probably occur sporadically all over the Altiplano and the desert. But they are particularly characteristic of the plain southeast of Oruro and of the Pampa de Islay, where they are well known from the fact that the Arequipa railway goes through them. These dunes, which are known as *médanos*, are crescentic in form like the *barchans* of central Asia. They lie with the horns of the crescent away from the effective wind which puts them frequently in motion.

The undrained hollows of the Western Cordillera and Altiplano act as local base levels, below which gravity cannot act, and their surface is being gradually raised by deposit. Where water brings salts in solution to these hollows, or where gaseous volcanic emanations reach the stagnant water from below, the water becomes highly saline; and on its evaporation the salts crystal-

lize. Thus the salars are formed. Their composition varies from the surface downwards and from the edge towards the center. But in general they form nearly flat expanses of dazzling whiteness. Their surface generally is much broken and is difficult to cross, and the sharp buckled salty crust injures the feet of animals. Where rails are laid over their surface the bed has constantly to be remade, since crystallization goes on and causes the surface to bulge by pressure from below.

In the foregoing description much has been said of volcanoes and of geological faults. Both of these of course are evidences of the instability of the earth's crust; and before leaving the subject it is necessary to add a few words on present conditions in this respect. There are now no volcanoes in the area under discussion which are in active eruption or which are definitely known to have erupted in historical time. But several of the peaks of the Western Cordillera still emit steam and volcanic gases from their craters or from fumaroles on their flanks. This is true of Misti, Ubinas, Tacora, and Taapacá.

That the earth's crust is now more stable in the east of our area than on the Pacific slope is made clear by the fact that serious earthquakes occur only in the latter; although some geological faults in the Eastern Cordillera are still marked by the presence of springs of high temperature. Earthquakes on the Pacific littoral have been numerous and severe in historical times. Arequipa was destroyed by an earthquake in 1746, Pisagua in 1868, and Arica successively in 1605 and 1746.

CHAPTER III

MINERALS AND MINES

Incomparably the most important facts regarding minerals in the area are, first, that Chile produces 99 per cent of the world's supply of nitrates and, secondly, that Bolivia produces about 21 per cent of the world's tin.[1] In 1918, 2,919,000 tons of nitrate were exported by Chile, and of this 495,000 were embarked at the ports of Caleta Buena, Caleta Junín, and Pisagua, the remainder of the Chilean export coming from ports to the south. Thus approximately 19 per cent of the world's supply of nitrates comes from a narrow strip of land in the La Paz sheet area lying for the most part immediately to the west of the longitudinal railway south of Jazpampa.

In 1915, Bolivia exported 36,492 metric tons of tin concentrates, which on smelting produced 21,900 tons of metal; and this was 17 per cent of the world's supply. Of the 36,000 tons of concentrates about 21,000, representing about 10 per cent of the world's tin supply of that year, were produced in thirteen groups of mines situated in the map area. Moreover, the world importance of these mines presumably increased after 1915, for in 1917 and 1918 Bolivia supplied not 17 per cent of the total tin but 21 per cent.

The region also supplies important contributions of borax and of copper and could turn out a somewhat larger proportion of each. The special demands for tungsten and bismuth during the World War resulted in an intensive production of these minerals in Bolivia; but it remains to be seen whether the country's importance as a source of them will be maintained under normal conditions. The silver and gold production of this part

[1] The mineral deposits of the region and their extraction have been so admirably treated by Miller and Singewald in their recent work (55) that the brief statement made on this subject in the introductory chapter will be elaborated here only in its most salient geographical aspects.

of Bolivia has now merely local importance, and this is true also of sulphur and salt, although the sulphur deposits on the Chilean side of the border have a prospect of becoming very important. Moreover, it is a matter of great interest to the world that the chief commercial source of iodine is the nitrate deposits of Chile.

The various minerals occur in distinct geographical zones which follow broadly the outcrop of the various geological systems and therefore lie more or less parallel, trending from northwest to southeast. The nitrate zone, although it does not extend much north of Pisagua, lies parallel to the coast. The sulphur, being found in active or extinct volcanoes, lies entirely in the Maritime Cordillera; likewise the borax, ultimately derived from volcanic exhalations, is now found in the lake beds of this Cordillera, where it has crystallized. Copper occurs in the native form and has been injected into the interstices of the reddish sandstones of the western Altiplano from Corocoro southeastwards; while other copper ores are found in continuation of this zone northwestwards along the shores of Titicaca. The other minerals—tin, tungsten, bismuth, silver, and gold—are all found in the rocks of the Eastern Cordillera, while gold is extracted from the alluvial valley deposits derived from them. Lastly, if oil be later found in this section of Bolivia, it will lie in the sub-Andine zone which crosses the northeast corner of the La Paz sheet and possibly also on the Altiplano, contained in the anticlines which follow the general strike of the rocks there.

The region as a whole has long been one of the most famous mining countries of the earth, and it is well known how the treasure of the Incas was the original lure of the *conquistadores*. Before the Spanish Conquest silver, gold, and copper were mined by the Aymará and Quichua Indians of the plateau.[2] Although the mineral wealth of the Andean region probably meant little to the Indians in the earlier stages of their development, yet as their culture advanced they exploited some of the deposits of gold, silver, and copper for the manufacture of tools,

[2] A fuller statement of general conditions in this early period will be found at the beginning of Chapter IX.

household utensils, and ornaments. With the growth in the demand for such metals, mining became an important industry, and the making of metal objects became one of the features which characterized their culture.

Gold was obtained from placer mines, one of the most notable of the gold-yielding districts being the valley of La Paz, known in ancient times (and still known among the Indians) as Chuquiapo, "heritage of gold," with its neighboring district Chuquiaguillo or Orco-jahuira. The region of Inquisivi also contains gold deposits that are said to have been worked in pre-Conquest days. In fact, from those regions of the Colla (or Aymará) country, and particularly from the region about Carabaya, just north of Lake Titicaca and just beyond the border of this sheet, came a large part of the gold of the Inca empire.

Silver was mined in a number of places. One of the most noted of the silver-bearing districts was Porco, which like the world-famous Potosí lies just over the southeastern border of this sheet. Some of the veins in the Oruro hills were also said to have been worked before the Conquest. The Indians had learned to smelt the silver by means of pottery furnaces (*guayras*), which were set up upon the higher slopes of the hills so as to receive a constant natural draft. The molten metal ran out from openings left in the bottom of the furnace. Charcoal brought from the timbered hills of the eastern slope of the Andes was used for fuel, as was also probably the dried dung of llamas (*taquia*), still the most common combustible on the plateau.

Copper was very generally used among the Indians for their tools, weapons, and such ornaments as the *tupus*, long pins with the head in shape of a spoon, with which the women fastened their shawls. Sometimes pure copper was used, sometimes a bronze which was long thought to have been an accidental alloy but which is now known to have been made by the Indians.[3] The copper was obtained from the copper belt that runs southeastward from Lake Titicaca through the Altiplano. Ancient mines are spoken of at Cerro de Scapi near Chuyca in Lipez, at Tara-

[3] Erland Nordenskiöld, (113).

buco in Chichas, and at Caraguara (modern Corocoro) in Pacajes. It is thought that the art of producing bronze was known even in the very ancient period represented by the ruins of Tiahuanaco, although it did not become common or widespread until late Inca times. It has been ascertained that tin was added to the copper in the making of tools and weapons, in order that the articles might then be better hardened by cold hammering,[4] and it is thought that a still larger percentage of tin was used in bronze ornaments in order that they might be more easily molded. That tin was used alone seems doubtful, although in one instance pure tin objects that seemed to be of pre-Conquest origin have been found. A number of tin deposits were worked in this region, however, in Inca times, notably that at Carabuco near Lake Titicaca, and it is probable that barter carried this material to distant parts of the empire.

About the mining centers settlements had grown up, composed of men trained in the process of ore extraction and in the arts of simple metallurgy. Mining, however, did not reach any extensive development even during Inca times, since the uses to which metal objects were put were quite restricted. All the precious metals were claimed for the royal household, either for adornment of the person, or for the beautifying of palaces and temples. No metals were used for money, so far as known, commerce being carried on entirely by barter.

When the Spaniards had become masters of the Inca empire in the sixteenth century they at once initiated a feverish campaign of mining activity, devoting their attention almost entirely to the precious metals. With the establishment of a system of forced labor (*repartimientos* and *mitas*) the mines already being worked by the Indians were extended, and every Spaniard became a prospector for new deposits. As a result of this it is probably no great exaggeration to say that every square league of hilly country occupied by the Spaniards bears some sign of having been explored for its mineral wealth. The richest of all silver mines—

[4] H. W. Foote and W. H. Buell: The Composition, Structure, and Hardness of Some Peruvian Bronze Axes, *Amer. Jour. of Sci.*, Vol. 34, 1912, pp. 128–132.

those of Potosí and Porco—lay just beyond the area we are discussing; but the Cerro de Oruro, opened in 1568, was soon almost as important. The Spaniards introduced improvements in the extraction of the metals. Extensive deposits of mercury were found in Peru (near Guamanga) in 1567, and this metal was imported and applied to the reduction of silver, thus making possible the working of lower-grade ore than formerly. The ore was milled by horse power or by water power, where that was available, reservoirs being constructed to increase the resources.

With the richer and more accessible ores of silver worked out, and with gold more easily obtainable elsewhere, mining activity fell off in the eighteenth century; and, when the attention of prospectors was again directed to the Bolivian plateau in the nineteenth century, it was no longer gold and silver but the baser metals—tin and copper—which drew them thither.

In comparing the output of metals during the earlier periods with that of today it is necessary to bear in mind, first, that under the Incas and earlier Spaniards there was no question of making a mine pay, for the amount of labor available was limited practically only by the population—the labor being forced, and, secondly, that mining for the most part took place at or near the surface; and we must remember further that many mines formerly rich in silver ores now yield only tin and that the depreciation in the value of silver some thirty years ago greatly restricted the output of the less valuable ores.

The Nitrate Fields

For nearly a century scientists have sought to explain how nitrogen has become fixed in these coastal pampas as sodium nitrate or "Chile saltpeter" on such a large scale, and while the problem is still unsolved it is clear that a very important element in the genesis of the mineral is the regional peculiarity of the nitrate fields. This peculiarity results from the coincidence of several features. The high range of the Maritime Cordillera causes regular precipitation of moisture which drains westward. The range is bordered by a piedmont belt of detrital material—

thicker near the mountains and sloping gently westward. The surface of the water table in this detritus also slopes westward and comes nearer to the surface in that direction; but the water is prevented from escaping to the sea by the coastal hills, composed of crystalline or other compact rock and higher than the lower piedmont east of them. The climate, as we have seen, is arid, and evaporation by day is intense; but humidity often reaches saturation at night, when sea fogs drift over the coastal lands. Discussion regarding the origin of the nitrates has recently been summarized by authors who come to different conclusions.[5] The explanation offered by Miller and Singewald may perhaps be stated in a few words. They point out that the ground water is evaporated in proportion to its nearness to the surface, and the process therefore is most intense near the western edge of the piedmont where more water will be raised by capillary action than elsewhere. Such water if it contain nitrates in solution will deposit them on evaporation at or near the surface—in the same way, indeed, that sea salts are deposited near the shores of the Red Sea above sea level. These authors are not convinced that the underground waters of the district necessarily carry an unusual amount of nitrate in solution and consider that the coincidence of such soil and atmospheric conditions with the resulting long continued efflorescence of the salt may be sufficient to account for the unique deposits of northern Chile.

Previous investigators, however, have mostly sought for some abnormal fixation of nitrogen in the region. Their theories may be divided into four classes. The first attributes the nitrates to the slow oxidation of masses of seaweed accumulated when the area formed a shallow sea bottom. The second group assumes that a guano deposit about the shores of a salt lake or sea inlet was either flooded by salt water and so formed sodium nitrate, or after forming calcium nitrate was slowly liquefied by night dews and then coming in contact with the salt of the salars was

[5] Joseph T. Singewald, Jr., and Benjamin L. Miller: The Genesis of the Chilean Nitrate Deposits, *Econ. Geology*, Vol. 11, pp. 103–114; 1916. W. L. Whitehead: The Chilean Nitrate Deposits, *ibid.*, Vol. 15, 1920, pp. 187–224. Both papers contain bibliographies.

converted to sodium nitrate. The third group attributes the work of nitrification to organisms acting upon ancient vegetable matter in the soil, the nitrates being concentrated by water and evaporated as outlined above. The last group invokes the aid of electricity as an oxidizer of atmospheric nitrogen—either electrostatic tension accompanying the coastal fogs which invade the pampas at night or electric storms in the cordillera. One author believes that the nitric acid from the atmosphere forms nitrates only when rocks containing a high percentage of sodium are present, which is the case in the porphyries of this part of the Andes.

Whitehead[6] believes that the source of the nitrates is volcanic material, especially tuffs, in the neighborhood. He points out that the deposits lie on the gentle hill slopes on the west above the level of the pampa, and he shows how the salts, dissolved mainly by dews from the rocks of the hilltops to the west, have been carried progressively downward by the occasional rains. He regards the ground water as a possible source only in rare cases, since the débris of the pampa is of too loose a character to allow extensive capillary action to take place. It would seem possible, however, that even if this theory is the right one in general it is necessary to invoke another in the fields east of Pisagua, for the hills there are not composed of volcanic rocks but of limestone.

The process of mining or "extracting" the nitrates is simple. The upper layers which vary as to composition and thickness are broken by blasting; and the rich *caliche*, which has an average thickness of about one foot, is dug out for the most part in open workings. The material is then taken to the *máquina* or refining plant where after being crushed it undergoes a succession of boilings in vats. Thence the solution flows by gravity to huge evaporation pans where the salt is recrystallized. If it has 95 per cent purity, it is exported for agricultural purposes; if its purity exceeds 96 per cent, it is marketed for chemical manufactures. Iodine is obtained as a by-product by a very

[6] *Op. cit.*

simple treatment of the mother liquor after the nitrate has been crystallized out.

Nitrate extraction has produced an industrial oasis in the desert. Machinery, food, and fuel all have to be imported, the latter being mainly oil from Peru or California. The refining could not be effected without adequate water; and this, as we shall see below, is obtained from the ground water. It is interesting to note that the materials for the manufacture of blasting powder are found locally—saltpeter, sulphur from the Cordillera, and charcoal (formerly) from the roots of extinct forests buried in the sands. But charcoal is now replaced by imported coal dust.

Mining in the Western Cordillera

As there is no other important mining activity west of the Maritime Cordillera we may pass to this range, merely noting that the lomas of the coast and the crystalline foothills have in the past produced valuable copper ores, notably near Ilo and about the headwaters of the Río de Moquegua, and at any time metal mining may take a fresh start along the western side of the Andes. One copper mine, at Cerro Verde south of Arequipa, has already been reopened and is exporting its ore to Mollendo.

The group of volcanic peaks east of Arequipa encloses a basin with no outlet—the Pampa de Salinas. Formerly it contained a lake, but now water lies there only in the wet months, so that the bed is virtually a salar. A large part of the salt beds consist of boronatrocalcite (ulexite) which is the chief source of borax. The position and impermeable character of the bed points to an origin due to boric exhalations—derived from the volcanoes—having penetrated the water from below. The material from this bed is dried in ovens and exported on llama or mule back to Arequipa. At present this salar produces only a small proportion of the world's borax supply, the major part of which comes from the similar but greater salar of Ascotan, south of our region. But, when the projected railway to Arequipa is built, a much greater output is anticipated. A further source of borax has

been located at Chilicolpa on one of the head streams of the Mauri, but this is as yet undeveloped.

There are probably few volcanic peaks in the Western Cordillera which do not have sulphur deposits as a witness of their recent activity, and the digging and collection of it form one of the occupations of the mountain Indians—the crude sulphur being carried by them down to the nitrate fields, there to be used in making blasting powder. From the standpoint of production, however, the volcano of Tacora is by far the most important locality in the Andes, while there are other important deposits in the vicinity of the volcano of Isluga (19° 10′ S.). The deposits of Tacora are still in process of formation in solfataras; the sulphur is extracted simply by digging, which is carried on by Aymará Indians who come from the Bolivian side for periods of work. The mining is often interrupted in winter by snow. The sulphur is refined by sublimation in iron retorts, the local yareta shrub supplying the fuel. With the railway station of Ancara a few miles away these mines can undoubtedly look forward to supplying foreign markets with sulphur.

Mining in the Western Altiplano

Native copper is of commercial importance in only two places in the world—on the shores of Lake Superior and at Corocoro. The occurrence on the Altiplano of the metal in its pure state was of great importance in prehistoric times since it led to the malleable copper being employed before sufficient metallurgical knowledge had been acquired to enable the miners to extract the metal by smelting the commoner ores of copper. The native copper at Corocoro is intimately associated with the grains of the sandstone and occurs in the neighborhood of one of the main geological faults of the plateau, to which reference has been made. The copper ore, like other minerals of the Altiplano, was formerly exported on llama back to the coast; and the cost of exporting the heavy product in this manner long delayed the full development of the mines. But improved transport facilities[7]

[7] See below, p. 182.

culminating in the opening of the railroad to Arica have greatly simplified the export of the copper concentrates, from which about 6,000 metric tons of the metal are now procured annually, and the mines are probably entering upon an era of increased prosperity.

Mining in the Eastern Cordillera

The map on Plate II shows the position of the more important mines falling within the La Paz sheet. For the metals tin and copper conventional signs are inserted indicating the amount of concentrated ore produced in 1915, the last year for which the writer has had access to detailed statistics. It will be seen from this map that the mines of the Eastern Cordillera fall in two zones extending from northwest to southeast, the one in the Cordillera Real including all the mines from Milluni to Berenguela, and the other beginning at Oruro and including all mines to the southeast of it. It will be noted that the second zone starts at the latitude of the supposed structural break in the Cordillera, to which attention was drawn in Chapter II. It is not necessary here to draw attention to the mineralogical distinctions between these two zones; but it must be pointed out that, while both produce the metals tin, silver, tungsten, and bismuth the more southerly has by far the greater output of tin and it alone still carries a large amount of silver. In passing it should be noted that in the extension of this zone, beyond the sheet limit, occur the remaining important tin and silver mines of Bolivia. Gold is practically restricted to the northern zone. This metal, while it occurs in thin threads in many of the rocks of the Cordillera Real, is not found in sufficient quantity to repay the working of the lodes. It has been extracted by washing in the valleys since very early times; but the only placer mine which has been successful in recent years is in the Chuquiaguillo valley north of La Paz.

We have seen that silver was the main attraction for the early Spanish settlers in this region, and with easily accessible lodes and practically unlimited labor they produced enormous

quantities of the metal. It has been estimated that from 1553 to 1910 the mines of Bolivia produced 48,800,000 kilograms of silver, and of this 30,000,000 were credited to the silver mountain of Potosí which lies just outside our area. Oruro, Colquiri, and Colquechaca have all been great silver producers; and the city of Oruro in 1678 had a Spanish population of nearly 38,000 and at least as many Indians, or a total of about five times its present population. Today the chief silver mines of Bolivia are outside the region under discussion, and only Colquechaca and Colquiri are producing this metal in quantity.

On the other hand, the tin mines in the Uncia-Llallagua district are amongst the richest in the world and together they produce about three-sevenths of the Bolivian supply of that metal, while the Oruro, Huanuni, Morococala, Totoral, and Avicaya tin mines are of great importance today. A wide stretch of the high plateaus southeast of Oruro is formed of thick beds of andesite lavas which in the past have flooded the older denuded surface. These volcanic beds doubtless conceal much of the metalliferous rocks, as the richest lodes occur about its southern and western margins—Llallagua, Huanuni, and Negro Pabellon —or, as at Morococala, in hills of the older rock which protrude through the andesite.

One of the most striking features of the mines of the La Paz sheet is their great altitude. Some of them are responsible for leading important population groups far above the limit of comfortable living and into a zone which would otherwise be uninhabited. The heights above sea level of the leading mines are in round figures: Morococala, 5,000 meters, Colquechaca and Caracoles, 4,800 m.; Milluni and Araca, 4,500 m., Uncia, 4,400 m.; while Oruro, Huanuni, Colquiri, Totoral and Avicaya and Llallagua are all at about 4,000 m. Manual labor at such altitudes is of course possible only for the native Indians. The mines formerly had to rely entirely upon the local sources of fuel, either taquia, yareta, or charcoal from the forests. But imported fuel, and especially oil, is gradually taking their place. The ores of all metals are concentrated mechanically or by hand

sorting at or near the mines and until recently have all been exported in this condition. But tin smelting has made a start both at La Paz and Arica. Since 1913 the mines have had two railroads at their disposal—to Antofagasta and Arica respectively, and at present it looks as though the export of all ores in the area will eventually take place from Arica.[8]

[8] See below, p. 183.

CHAPTER IV

THE OCEAN

The part of the Pacific Ocean which is included in the La Paz sheet requires some description, for certain of its characteristics are of peculiar interest in themselves and have in addition an important bearing on the geography of the land. The South Pacific Ocean is shallowest in the center; near its eastern and western limits it exhibits profound depth. The marginal hollow on the east is known as the Atacama Trench, which extends from about latitude 10° S. to 28° S. and forms part of a wider and longer though shallower basin. The basin and trench form a feature comparable in magnitude to the Andes themselves, and these land and ocean features have to be considered together in discussing the major relief of the earth's crust. Without entering into such topics we may note here in passing that in the spheroidal surface of the earth it is such depressions as the Atacama Trench which alone form concave hollows. The soundings in this trench are few in number, and we have consequently but a very general idea of its shape. But it seems certain that its depth varies considerably from place to place; and while its slopes in general are probably so gentle that, were the sea removed, they would scarcely be perceptible to the eye, yet in places there are high submarine precipices. This has been demonstrated by Agassiz, who recorded soundings close together in the latitude of Callao of 836 and 5,706 meters. The only men other than scientists who are directly interested in the form of the ocean floor at such great depths are those concerned in the laying of submarine cables. All three of the main cables on the west coast of South America cross the area represented on this map, one close to the shore and the other two at depths of between 2,000 and 4,000 meters. These latter link Callao with Iquique, and, instead of following the most direct track between

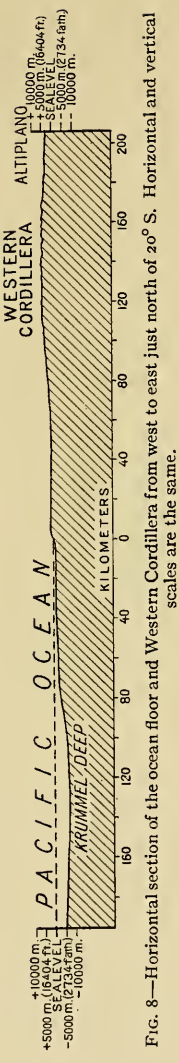


FIG. 8.—Horizontal section of the ocean floor and Western Cordillera from west to east just north of 20° S. Horizontal and vertical scales are the same.

these ports and so traversing the deep trench, they keep to shallower floor and follow contour lines rather closely.

From the recorded soundings it is possible to recognize four—perhaps five—separate abysses in the Atacama Trench. The deepest of these, which reaches at least to 7,635 meters (4,175 fathoms), lies to the south of our area; and Krümmel Deep, of which a large portion appears on the La Paz sheet, exhibits a bottom below 6,500 meters (maximum recorded, 6,827 m.). This represents a somewhat greater depression below sea level than the elevation above it of the Western Cordillera. The horizontal distance between these parallel features—the Cordillera crest and the trench—is about 300 kilometers, and the present coast line is about midway between them. The comparative relief on land and sea is shown on Figure 8, which represents the slopes on the true scale.

The waters which are represented on the map form part of one of the major ocean streams of the earth—the Humboldt, or Peru, Current; the entire body of water within a range of about 100 miles of the coast being constantly on the move northward with an average velocity of from ten to fifteen sea miles in every twenty-four hours at the surface decreasing downwards probably to a slow creep along the bottom. We shall see that the consequences of this fact are far-reaching. Without discussing here the causes of oceanic circulation let us recall that an important element in setting up the currents is variation in density, which

depends largely on temperature and on relative salinity; and this in turn leads us to evaporation, which is closely related to atmospheric temperatures. On the other hand, surface drifts are set up by the prevailing winds, and the deeper waters tend to be carried along with these by friction.

All these elements help to bring a mass of water from the sub-Antarctic Ocean northward along the west coast of South America to the neighborhood of the equator as an ocean current. Moreover, since moving objects of all kinds in the southern hemisphere are deflected to the left by the earth's rotation, the current would move more and more strongly towards the northwest as it approached the equator. This deflection is accelerated in the case of the Humboldt Current by the changed trend of the coast beyond Arica. Apart from this the upper layers are blown along more rapidly in the same direction by the prevailing southerly and southeasterly winds, and the current in places attains the velocity of 1½ knots (2.75 km. per hour). Over the open sea in this area the southeasterly trade wind predominates to a greater extent than it does on the coast, where it is pulled notably inwards to the land; and the result is that the surface water is constantly being driven away from the coast south of the latitude of Arica and north of that place is carried along parallel to the coast more rapidly than the lower strata. To maintain the level there is a steady up-welling of deep water to the surface, and this water is relatively cold. Deep ocean water coming to the surface in any part of the world would be relatively cold, but here, owing to the Humboldt Current the ocean on its floor has a lower temperature—below 35° F. (1.67° C.)—than the water to the west of it. The records concerning the water actually represented on the map are meager. The data assembled by Hoffmann[1] bring out the very gradual increase of average surface temperature from south to north. In the latitude of Arica this average is given as 18.1° C. (65° F.), whereas the average for the South Pacific Ocean between latitude 16° and 20° S. is 23.5° C. (74.3° F.).[2] Murray in his maps of ocean

[1] Paul Hoffmann, (80), p. 76. [2] Otto Krümmel, (79), Vol. 1, p. 400.

surface temperature shows[3] the area as having a minimum (Aug.) between 50° and 60° F. (10° and 15.56° C.) and a maximum (Feb.) between 70° and 80° F. (21.11° and 26.67° C.); but this annual range would appear to be too great, for Coker[4] after taking over 300 readings between January, 1907, and July, 1908, along the whole coast of Peru as far south as Mollendo (western limit of the La Paz sheet) arrived at the tentative conclusion that the surface waters of the current undergo little change of temperature either from month to month or place to place. This at least is true of the water near shore where the maximum up-welling takes place. Here the surface temperatures are lowest and most uniform. Hoffmann gives temperatures for Valparaiso (33° S.), Coquimbo (30° S.), and Callao (12° S.) which show less than 1° C. of difference between Coquimbo and Callao in March and a similar difference between Valparaiso and Callao in November and December. Observations further point to an increase seawards of at least 1° C. for every 15 miles. Buchanan[5] who made temperature and other observations on this coast in April, 1885, records 67° F. at Arica and 73° crossing the bight to the west and emphasizes the contrast in color from the green, cold water of the coast to the deep ultramarine water from ten to fifteen miles off shore.

We have seen that the Humboldt Current is cool and stable in temperature. In winter, sea and air temperatures are almost identical. The British survey ship *Beagle* in sailing from Iquique to Callao (in July, 1835) records both as between 60° and 63° F. (15.6 and 17.2 C.).[6] But in summer the water is cooler than the air over it and much cooler than the air over the coast lands. The early *conquistadores* realized this fact and made a practice of submerging their wine to cool it in the absence of an ice supply. The important climatic features which result from this temperature difference have already been noted. Equally important is the effect which low ocean temperature has in the development

[3] John Murray, (82).
[4] R. E. Coker, (83).
[5] John Y. Buchanan, (81).
[6] Robert Fitz-Roy, (30).

of living things in its waters. Wherever the cold bottom water wells up—as in the northwest and southwest coasts of Africa, off California and northern Mexico, and in our region—the ocean abounds with life of all sorts. But Buchanan, with wide oceanographical experience, states[7] that "no waters in the ocean so teem with life as those of the west coast of South America. A bucket of water collected over the side is turbid with living organisms (visible and microscopic), the food of countless shoals of fish who in their turn afford prey for innumerable schools of porpoises" and, as we shall see, for immense numbers of seals, sea lions, and birds also.

Four physical features of these waters combine to make them a leading area for the propagation of marine life. These are the relatively low salinity, the lowness and stability of temperature, and the upward movement of bottom water. Low salinity and temperature help absorption of oxygen and nitrogen from the air at the surface, and the marine plants and animals are able to retain these elements in the water by their physiological processes. Moreover, low salinity favors solution of silica by water. Silica is supplied constantly by the volcanic and other dust from the land, and it is an essential to the skeletons of many of the humbler forms of life. The microscopic plants such as algae, whose nitrogenous tissue feeds the crustacea, etc., live in the light zone, i. e. near the surface. At death they sink and in most parts of the ocean remain below; but here the coastal up-welling again restores them to the light zone, there to be decomposed and so to furnish an unending source of material for new plant life and hence an unending supply of the higher forms of life.

The Pacific as a whole is a relatively calm ocean, and in this section storms are most infrequent. The trade winds blow with a moderate force—on the Beaufort scale 3½ in winter and 4 to 4½ in summer. A sailing ship before a wind of this force with shortened sail would travel under 5 knots in winter and some 6½ knots in summer. But, as the current and wind act together,

[7] John Y. Buchanan, *op. cit.*

these speeds are increased by nearly 1 knot. It is worthy of note that the coasting steamers charge a 10 per cent increase in fare on the southerly as compared with the northerly journey. For some two centuries after the Conquest the Spanish navigators sailing southward to Chile hugged the coast, and the voyage from Callao to Valparaiso commonly occupied twelve months or more. It was not until the early eighteenth century that a bolder spirit sailed out on the ocean and, by utilizing the prevailing westerlies in southern latitudes, reduced the passage to one month. While storms are seldom experienced, the sea is never still, and the constant swell produces breakers along the whole coast. This makes it impossible for larger vessels to come alongside anywhere, and landing is often difficult for small ships and lighters even at the ports and coves. These are few in number, as is to be expected in such a smooth coast line. Caleta Buena, considering its exposed position, is singularly free from bad surf, and the loading of nitrates from the cliff railroad to the lighters and so to the vessels is seldom interrupted. Caleta Junín, another nitrate port, on the other hand, has many "surf days" on which loading work is suspended. Pisagua with its southern protection of Punta de Pichalo is a relatively good port for this coast. Caleta Chica is small and well protected but is used chiefly as a refuge. The port of Arica, although it has a mole 250 yards long, has wharfage only for lighters. The anchorage is the best on the coast, but from June to August the rollers are often so heavy as to stop all traffic in the port. The roadstead of Ilo forms one of the best harbors, since "surf days" are unknown. On this coast tides scarcely enter into navigational considerations, the average rise at spring tide being only in the neighborhood of five feet (1.5 m.).

CHAPTER V

THE CLIMATE

Continuous meteorological records, mostly for short periods, have been kept at six stations within the area of the La Paz sheet and at six around its borders. The following discussion of climatic conditions is based upon these records and upon isolated observations made by travelers and residents. Such deductions as are drawn regarding cause and effect must be taken as tentative, in view of the character of the data available.

The facts regarding stations for which continuous meteorological records are available are as in Table I.

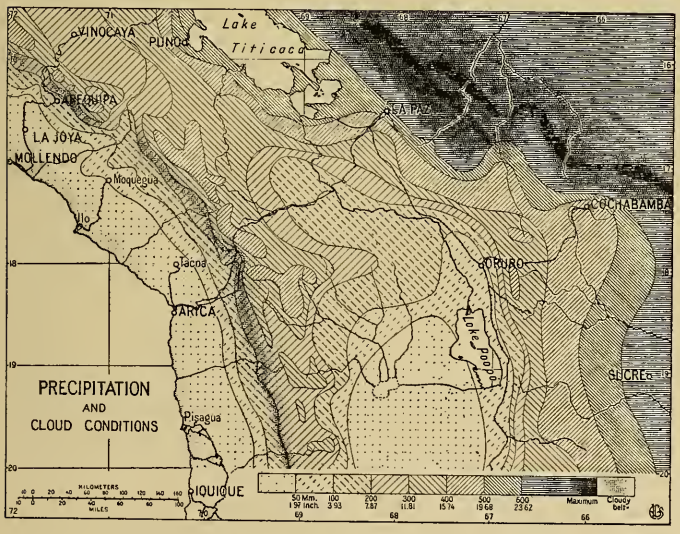


FIG. 9—Distribution of the mean annual precipitation and of the belts of cloud. Names of stations for which meteorological data exist are printed in capitals.

TABLE I—METEOROLOGICAL RECORDS

STATION	ALTITUDE (METERS)	PERIOD	NATURE OF RECORDS					
			TEMPERATURE	PRESSURE	HUMIDITY	PRECIPITATION	CLOUD	WIND
*Arica .	5	1905 onwards[1]	+	+	+	+	+	+
Iquique	9	1900 onwards[1]	+	+	+	+	+	+
Mollendo	25	Nov., 1888–May, 1890[2]	+			+	+	
Mollendo		Apr., 1892–Dec., 1895[2]	+			+	+	+
Mollendo		Apr., 1894–Dec., 1895[2]			+			
*La Joya	1,261	Apr., 1892–Dec., 1895[2]	+			+	+	+
*La Joya		Apr., 1894–Dec., 1895[2]			+			
*Arequipa	2,456	Nov., 1888–June, 1890[2]	+			+	+	
*Arequipa		Nov., 1888–Apr., 1890[2]						+
*Arequipa		Jan.–Oct., 1889 (less Mar.)			+			
Vinocaya	4,380	Nov., 1888–Apr., 1890[2]	+			+	+	+
Chosica	2,013	May, 1889–Sept., 1890[2]	+			+		
		July, 1889–Sept., 1890[2]					+	
Puno .	3,825	Nov., 1888–Mar., 1889[2]	+			+	+	+
*La Paz.	3,630	Mar., 1898–Apr., 1898[3]	+	+	+	+	+	+
		Aug., 1899–June, 1903[3]	+	+	+	+	+	+
*Cocha-bamba	2,557	Jan.-Aug., 1874–Jan.-Mar., 1876[4]						+
*Cocha-bamba		Jan., 1882–Dec., 1885[4]	+		+	+	+	
*Oruro .	3,706	Jan., 1885–Dec., 1888[3]	+			+		
Sucre .	2,848	May, 1882–Feb., 1898[3]				+		
		Feb., 1915–Mar., 1918[5]	+	+	+	+	+	+

Irregular observations of varying character were made in the mountains near Arequipa as follows: *Chachani Ravine, Jan., 1892—Mar., 1893; *El Misti summit, Oct., 1893—Dec., 1895; *"M. B. Station," Dec., 1893—Dec., 1895; Alto de los Huesos, Mar—Dec., 1895.[6]

* The asterisk indicates stations within the map area.

[1], [2], [3], [4], [5], denote sources given in Appendix C, Bibliography, viz: 1 (86), 2 (87), 3 (88), 4 (89), 5 (90).

+ denotes that records are available.

[6] Source for all these records is (87).

Temperature

In order to appreciate the great climatic variation throughout the area of the La Paz sheet we must bear in mind above all the very wide differences in altitude which occur—from over 6,000 meters down to sea level on the one side and to some 300 meters on the other. With the pressure at sea level normal this means a difference of temperature of some 30° C. (54° F.) between our lowest and highest zones. This difference of temperature is the most outstanding of the climatic features. It made such an impression on the white settlers that they recognized well-defined natural zones of altitude and temperature, the names of which are in common use: the Puna Brava from the snow line (about 5,000 meters) down to about 3,900 meters; the Puna, 3,900 to 3,350 meters; the Cabezera de Valle or valley head, 3,350 to 2,900 meters; the Valle 2,900 to 1,600 meters; and the Yungas below that. These names for the two lower zones apply only to the eastern slopes of the Andes. Mean annual temperatures in these zones, for places in each case about the middle of the zone, may be taken in order from highest to lowest as approximately: 7° C., 12°, 15°, 20°, 25°; the Fahrenheit equivalents being approximately 45°, 54°, 59°, 68°, and 77°.[7] Of the meteorological stations above-mentioned Vinocaya is in the Puna Brava, Oruro, Puno, and La Paz are in the Puna, none are in the Cabezera; though Cochabamba, Arequipa, and Sucre are near the upper limit of the Valle, which is sometimes referred to as the Medio Valle; La Joya is in the desert, and Mollendo, Arica, and Iquique are on the coast.

Almost everywhere on the plateau and in the low desert west of it the amount of cloud is small, and consequently radiation after sundown is very rapid. The examples given of daily variation of temperature (Fig. 11) for summer and winter periods bring this out clearly. The contrast of sun and shade temperatures is most striking in the Puna and higher. Figure 10 shows a series of temperature curves for seven stations of which

[7] On later pages centigrade degrees only will be given, but a table of equivalents will be found in Appendix D.

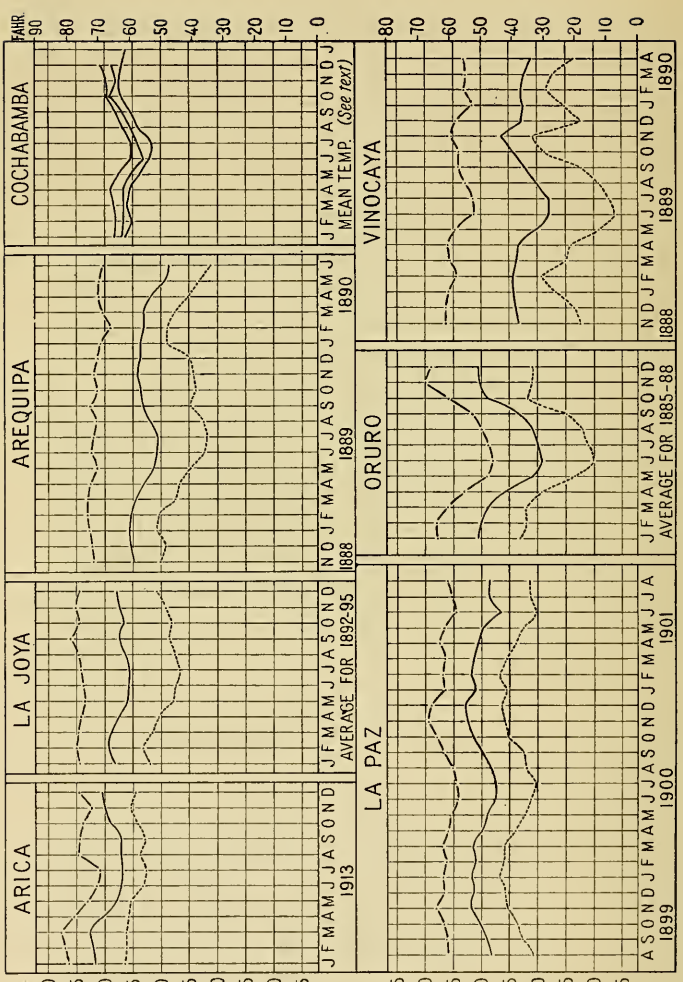


FIG. 10—Graphs showing monthly variations in maximum, mean, and minimum temperature at seven stations. Constructed from data published as follows (numbers refer to Appendix C, Bibliography): Arica (86); La Joya, Arequipa, Vinocaya (87); Oruro ('88–Mar.-Apr. 1898); Cochabamba (see text).

only Vinocaya is outside the area. The records from which they have been plotted supply data for one year or more in every case and include in four cases mean maxima, mean minima, and mean temperatures for every month. But for Oruro only maximum and minimum averages are available; and the mean of the two has been introduced to serve for general comparison. In the case of Cochabamba mean temperatures only have been published, and of these three sets of figures exist. All of these have been plotted, the curves having been derived as follows: upper, computed by Hann[8] from all observations of Von Boeck and said to be too high, since the readings were too numerous; middle, by Hann, using von Boeck's observations for 1885 only; lower, by Krüger[9] from observations for the period of Feb., 1900, to Jan., 1901. The mean annual temperatures corresponding to these three curves are 18.1° C., 16.4°, and 15.1° respectively.

The curves are arranged in ascending order of altitude from Arica at 5 meters to Vinocaya at 4,380 meters, and a glance will show the progressively lower temperatures in general. Cochabamba, however, is 100 meters higher than Arequipa, and yet even the lowest version of its mean curve is higher than that of the lower station. This is explained in all probability by the sheltered position of Cochabamba in a basin; and we shall see that the wind observations suggest a center of warmer air over this basin. Again, Oruro is only 76 meters higher than La Paz, but the curves are very different. Oruro is typical of the Altiplano on which it is situated and shows a much greater annual variation and much lower winter temperatures than La Paz, which lies in a sheltered valley and 500 meters below the rim of the plateau.

The seasonal movement of the sun over the area brings it vertical twice during the summer, in the end of November and early in January; and theoretically there should be two temperature maxima. The only trace of this in the curves, however, is

[8] Julius Hann, (91).
[9] Rodolfo Krüger, *Bol. Observ. Meterol. de La Paz*, No. 4.

in those for La Paz and Vinocaya. If the observations were for longer periods, however, it is possible that this feature would emerge more clearly. As it is, the curves for Arequipa, La Paz, Oruro, and Cochabamba exhibit a tendency to rise in the spring more steeply than they descend in the autumn. There is considerable variation in position of the maximum at the different stations between November and March; but the lowest temperatures are always in June or July.

If we compare the three stations west of the Cordillera we find that, save for one month at Arequipa during the rains, the mean maxima are always above 20° C., and the mean minima are never below 0° C. Of the three stations La Joya, in the middle of the desert, experiences the most regular temperature variation, its maxima and minima being almost always equidistant. The Arequipa curves show the smallest difference between high and low in January and February, that is during the rains.

In comparing the three high stations we may note the more equable temperatures of La Paz, with its mean maximum nearly always above 15° C. and its mean minimum never below 0° C. At Oruro we find six months with mean maxima below 15° C. and mean minima below the freezing point. At Vinocaya in an eighteen months period only six months show mean maxima over 15° C., and only one has a mean minimum over 0° C.

These curves do not give us a quite correct impression of the temperatures experienced by man on the plateaus because they are shade observations, and during the day men shun the shade. Everywhere west of the Eastern Cordillera the amount of sunshine is great, and its heating effect on account of the thinness of the atmosphere is high. Thus, while ice may be lying all day in shady spots, the sun's rays may be burning the skin of the white man in the open. The suddenness with which temperature drops when a cloud obscures the sun is one of the features which most impresses the traveler in these high regions.

We shall be able to appreciate more fully the effects of the altitudinal range, attenuated atmosphere, and absence of cloud, if we examine examples of daily variation in temperature.

Figure 11 represents a plotting of records for typical weeks in summer and winter at five of the above stations and a summer week for Puno in addition. Two features stand out in a general way at first sight, the reduction in temperature with increase of altitude and the great difference in daily range between the

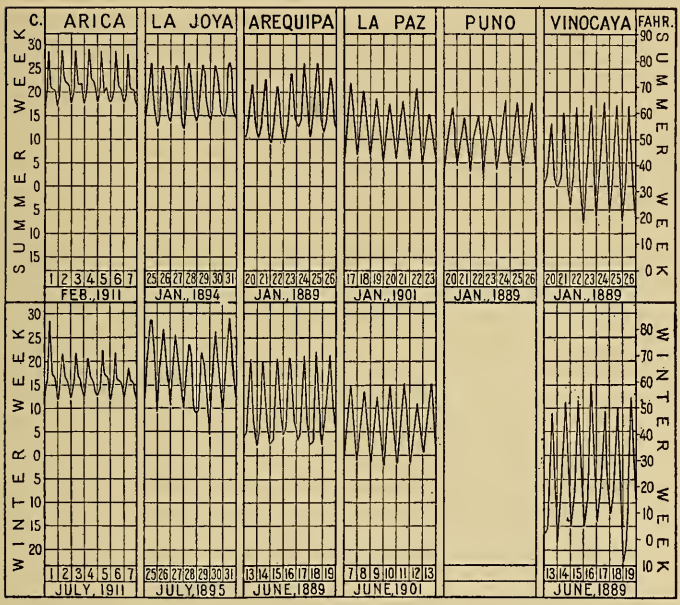


FIG. 11—Graphs showing daily variations in temperature for typical weeks in summer and winter at six stations. Constructed from data published as follows (numbers refer to Appendix C, Bibliography): Arica (86); La Paz (88); Remainder (87).

coast and the highest station. At four stations the range is greater in winter than in summer. Let us examine the graphs for each place in turn.

At Arica in summer the thermometer behaves with almost clocklike regularity. During the morning the temperature

mounts fast, reaching a maximum soon after noon. Then the sea breeze begins to blow, and the influx of cool air from the coastal waters causes a sudden drop in temperature, while after sunset radiation produces a further drop to the minimum. Observations for 7 A. M., 2 P. M., and 9 P. M. are almost identical. In winter the sea breeze blows with less regularity, and there is consequently more variation in maximum temperatures.

La Joya is a railway station in the desert 1,250 meters above sea level. Its greater altitude gives it lower summer temperatures than at Arica. The clearness of its desert sky gives it lower night temperatures throughout the year. The winter maxima are higher than those of Arica because the sky was overcast on all but the first day of the week at that place.

At both Arequipa and La Paz the extremes were markedly greater in winter than in summer, the La Paz thermometer going below 0° C. nearly every night in the June week. Puno is on the western shore of Lake Titicaca, and, although it is 100 meters higher than Oruro, it enjoys a much more equable climate, thanks to the stabilizing effect upon temperature of the large body of lake water. Observations are available for the months November to March, but these give ground for believing that the temperature curves are much more like those of La Paz, 200 meters below it, than those of Oruro. The mean daily range for the five months observed was between 3.6° and 18° C., and the variation from that was very slight.

The weekly curves of Vinocaya are probably a good representation of typical winter and summer conditions on the higher plateaus and along the lower slopes of the mountains which rise above them.

Pressure and Winds

The great differences in altitude of course lead to very large normal pressure variation throughout the region. It is the departures from these normals which produce pressure gradients and the consequent movement of air, or winds. We have a certain limited knowledge of wind direction and force through-

out the region, but the data regarding barometric variation are much too sparse to be of any use in explaining the winds observed. We must be satisfied, then, for the present with a statement of wind observations and, while offering suggestions as to causes, await further investigation before attempting complete explanation. Theoretically the area is entirely within the limits of the belt of southeast trade winds. But actually these regular winds with their normal direction seem to affect only the outer fringe of the eastern Andes and the ocean well away from the coast.

Winds on the Coast and Western Cordillera

In this western section of the area under discussion the normal trade winds do not blow; but the movement of air is, nevertheless, extremely regular, and seasonal variation is relatively unimportant. The factor determining the dominant winds is the contrast of temperature and pressure over ocean and land. The rapid heating of the low desert and mountain slopes as the sun climbs throughout the forenoon produces a strong indraft from the cool ocean, diverting the wind from its normal southeasterly to a southwesterly direction. This strong sea breeze—*virazón*—blows every afternoon in the year on the coast and presumably also in the desert. From sunset till after sunrise calm or a light land breeze—*terral*—prevails; but the amount of outflow in nowise compensates for the indraft of the virazón, perhaps because the general dominant movement of air is towards the equator.

Figure 12 shows wind roses for Arica. These bring out the marked uniformity of regimen throughout the year. The distinction between summer and winter is chiefly the greater proportion of morning and evening calm in the former. This feature as well as the more frequent land winds in winter (at 7 A. M. and 9 P. M.) seems to indicate that in summer the greater warmth of the continent keeps the relative pressure sufficiently low to prevent most of the outflow of air to the ocean. Wind conditions at Iquique and Mollendo—respectively just south and west of the sheet—are very similar to those at Arica. At

Iquique calms are less frequent, and at Mollendo the sea breeze rarely blows from west or south, southeast being a common direction. The general directions of coast and trade wind nearly coincide from Mollendo onwards, but there are many afternoons on which the air moves inwards from south to north. The virazón

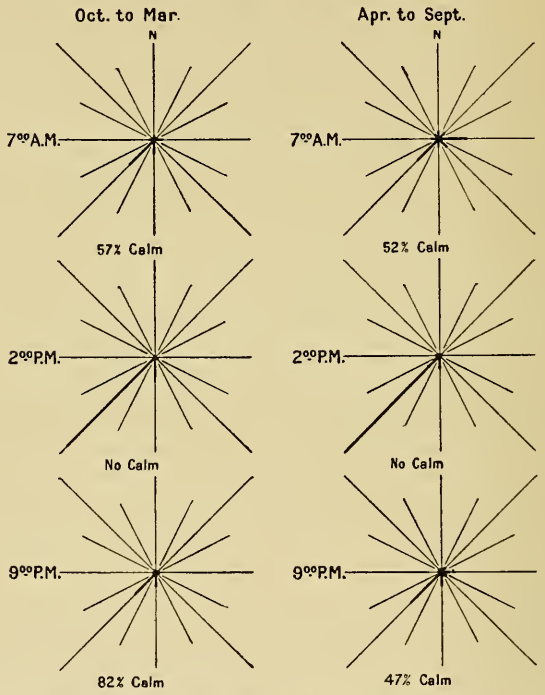


FIG. 12—Wind roses for Arica; constructed from the three daily observations for the period: Feb. 1911 to Dec. 1913, from *Annuario Meteorológico de Chile.*

is both an advantage and a disadvantage to the inhabitants of the coastal towns. On the one hand it brings sudden relief every day from the relentless heat (cf. Fig. 11), and on the other, as the raiser of surf it provides a serious obstacle to embarkation operations at every port.

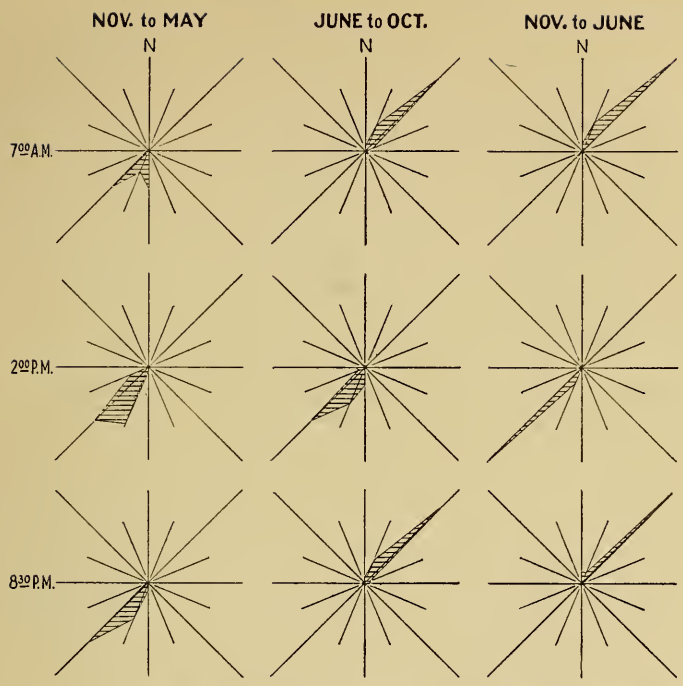


FIG. 13—Wind roses for Arequipa. Constructed from the three daily observations for the period: Nov. 1888 to June 1890; from *Annals of the Astronomical Observatory of Harvard College*, Vol. 39, Part 1, 1899.

Arequipa, 80 kilometers from the ocean and 2,400 meters above it, is still under the influence of land and sea winds. The published records for the period 1888–1890 show a remarkable change in conditions in the autumn of 1888. The wind roses on Figure 13 have, therefore, been drawn for three periods—two summers and one winter—with the first division at this abrupt change between May and June. A glance at the figure shows that throughout the entire period November–May, 1888, winds were from between south and west-southwest from morning till

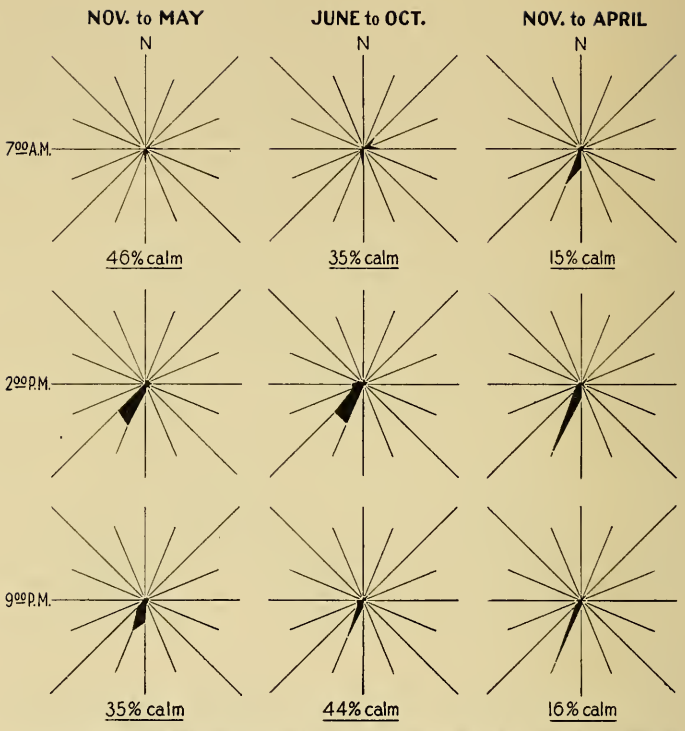


FIG. 14—Wind roses for Vinocaya. Constructed from the three daily observations for the period: Nov. 1888 to Apr. 1890; from *Annals of the Astronomical Observatory of Harvard College*, Vol. 39, Part 1, 1899.

evening; while in the year following only the afternoon winds—the sea breezes—had that direction, the morning and evening movement being consistently from northeast. In the year 1889–1890, then, there were twice as many observations of wind from the higher plateaus as there were of ocean wind. The Arequipa station is situated opposite the deep gorge of the Chili which would serve to divert any northerly or easterly wind to the direction observed. The observations of calm at this station are negligible.

The data for Vinocaya cover approximately the same period as those for Arequipa, and wind roses have been plotted (Fig. 14) for the same subdivisions of time, in order that comparison may be made. No change of conditions appears to have taken place here at the end of May, 1888, the proportions of the wind roses being fairly constant. There are some easterly and north-easterly winds, chiefly confined to the early morning, but even at 7 A. M. the winds were often from the south. From 2 P. M. till 9 P. M. at least the sea breezes were completely dominant at Vinocaya, which is 150 kilometers from the ocean and 4,380 meters above it. The morning and evening winds were mostly light, and there is an important percentage of calm weather.

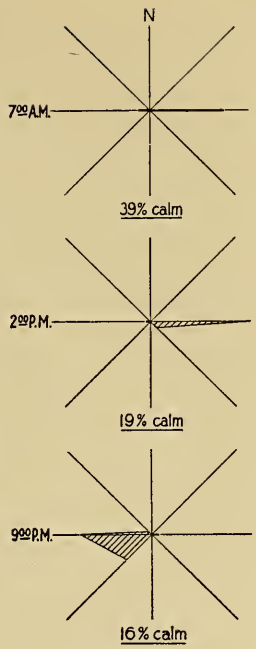


FIG. 15—Wind roses for Puno. Constructed from the three daily observations for the period: Nov. 1888 to Mar. 1889; from *Annals of the Astronomical Observatory of Harvard College*, Vol. 39, Part 1, 1899.

WINDS ON THE ALTIPLANO AND EASTERN CORDILLERA

The records for Puno cover only the summer of 1888–1889. The wind roses for this period (Fig. 15) seem to indicate the presence of a local air circulation in the Titicaca basin. Throughout most of the day, air is passing from the cool lake to the warm land, and by 9 P. M. we find a return current as the land cools. Of the winds observed at 7 A. M. and 2 P. M. 86 per cent and 96 per cent respectively blew from east or southeast, while at 9 P. M. 93 per cent were from between southwest and northwest. To prove that such a cause explains the Puno observations it would be necessary to have data from the other side of the lake.

But it may be noted that the recollections of a resident regarding the winds in the southern part of the lake only partially confirm the existence of such a simple system. This observer,[10] who knows the lake well, states that on the eastern shore of the lower lake there is a light early morning breeze from north or northeast, followed by a calm about 10 A. M. Towards noon a westerly wind springs up over the whole lake and becomes strong about 2 P. M. About 4 P. M. this veers to north, whence it continues to blow till about 9 P. M. Thereafter calm or light air from the lake follows. At Huaqui the westerly wind prevails in the early afternoon, then dies down, giving place often to a southerly breeze, to be followed in the evening again by a strong westerly lasting several hours. Winds are strongest and most continuous in August when they are chiefly westerly, while the smallest amount of wind is in June. In the rainy season—which corresponds in time to the records for Puno—he describes rapid changes of wind accompanied by hailstorms on the mountains and sometimes by whirlwinds. In this season the wind may blow from all points of the compass within two hours. From this and other accounts it is clear that at least in summer deep local depressions form and disperse over the Altiplano, but we have no evidence as to the direction they follow.

Several erstwhile residents of Oruro agree that by far the strongest and incidentally most unpleasant winds in that district come from the west, and this seems to apply also on the Altiplano to the south of Oruro. An official statement[11] gives the dominant winds as northwest, west, and southwest, of which the last are the strongest. From July to September they often have the force of gales and carry clouds of dust. They are known locally as *Cosecha de la muerte*—"harvest of death"—on account of the bronchial troubles which are engendered by the dust. It is doubtless in part owing to these winds that the city is sited on the east side of the hills, and the sand dunes to the south have been built up by these westerlies.

[10] Charles W. Foster, M. D., in a letter.
[11] Diccionario geográfico de la República de Bolivia, Vol. 4, 1904, p. 71.

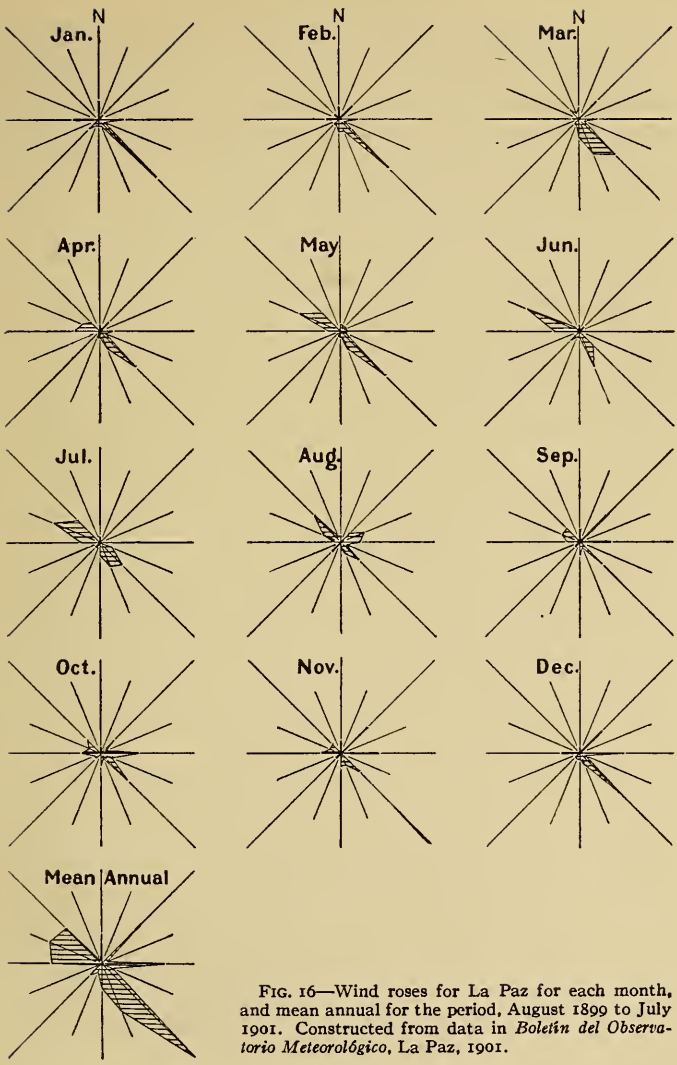


FIG. 16—Wind roses for La Paz for each month, and mean annual for the period, August 1899 to July 1901. Constructed from data in *Boletín del Observatorio Meteorológico*, La Paz, 1901.

Wind observations have been kept at La Paz, and some of them are set forth in Figure 16. La Paz is an extremely bad station from which to draw conclusions regarding air circulation, since the winds which reach it must necessarily be diverted locally so as to blow up or down the valleys which converge there. By making allowances for these features, however, it is possible to deduce certain useful facts regarding wind direction. The wind rose for the year shows that on by far the largest number of days the wind is southeasterly, while there are about equal amounts of wind from east and northeast and of wind varying between west and northwest. The first three directions correspond to the directions of the La Paz valley and the two passes in the Cordillera Real, and we may reasonably suppose that together the winds from these points are the trade winds, finding their way through and over the mountains. The winds from between west and northwest seem to correspond to the dominant winds of Oruro, and they are most marked in the winter months at both places. But they are less important than the easterly group, and thus La Paz is the first station we have discussed at which the normal trade winds are dominant. Residents of La Paz often notice a cloud banner streaming eastward from the summit of Illimani for days and even weeks on end. At first sight this might seem to indicate a westerly wind at an altitude of 6,000 meters—perhaps the anti-trade. But it may equally well denote the presence of the normal trade wind condensing the last of its moisture on the slopes of the mountain. The monthly wind roses for La Paz, which represent the averages of two years, show that winds with an easterly component prevail in all months except June and July and that from December to May southeast is the dominant direction.

Wind records for Cochabamba are unsatisfactory. They are available only for eight consecutive months of one year and the numbers of observations vary in the case of two months.[12]

[12] The records of H. Ugarte given by Eugen von Boeck, (89), p. 458, are for 1874, Jan.–Aug. and 1875, Jan.–Mar. In July and August 74 and 58 observations were made respectively with no indication of date or hour. In the case of these months, therefore, the totals have been reduced by the factors $^{31}/_{74}$ and $^{31}/_{58}$.

Roses have, however, been constructed (Fig. 17), and they possess some points of interest. The only mountain barrier close to Cochabamba lies to the north, and apparently it does not eliminate wind from that quarter. It will be noted that from January to March and again in May and June winds have a

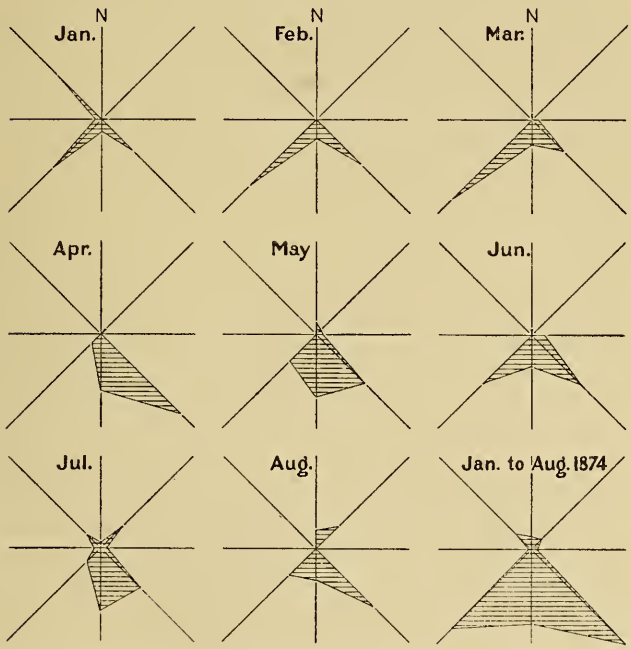


Fig. 17—Wind roses for Cochabamba for the period January to August 1874. Constructed from observations by E. von Boeck in *Mittelungen der K. K. Geogr. Gesell. in Wien*, Vol. 19, N. S., 1886.

strong westerly component but that otherwise southeast is the dominant wind direction. The combined wind rose brings out the great proportion of winds from between southeast and southwest.

Other observations were made in 1851 by Gibbon from December to April, generally at 9 A. M., and 3 P. M.[13] In the 283 observations winds were distributed as follows:

NE.	E.	SE.	SW.	W.	NW.	CALM
39	1	100	69	1	13	60

The windiest periods in Cochabamba are August–October and November–December. Like most of the other stations considered Cochabamba has most of its wind in the afternoon—starting here about 3 P. M. It is possible that the southwesterly winds here may be evidence of a low pressure area in the southern Altiplano; this is perhaps supported by the observations at Oruro and at Sucre (see below). But equally well would they be accounted for by a local depression in the relatively warm basin of Cochabamba itself.

We have but one other wind station to note, and it is some 70 kilometers east of the sheet area. Sucre is situated on a high plateau with only low hills about it, which do not divert winds in any appreciable degree. With this in mind we must attach importance to the somewhat surprising nature of the observations of wind direction. The records from which the wind roses on Figure 18 have been constructed are those of a well-equipped station maintained by Jesuits. They are believed to have been published regularly since 1915; but, owing to gaps in the series at my disposal, I have had to limit the data for discussion to the months Feb.–Dec., 1915, taking in January, 1917, in order to get a diagram for each month. From the regularity of the wind direction exhibited, however, these data may reasonably be taken as typical of any year. Throughout the entire year winds from northeast and north-northeast were by far the most frequent, the former prevailing for ten months and the latter for two, February and April. Appreciable divergence from these directions took place only between April and June and then mainly in the morning. Calm periods were noted only in the morning (7 A. M.) and

[13] William Lewis Herndon and Lardner Gibbon: Exploration of the Valley of the Amazon, a Report to the U. S. Navy Department, Vol. 2, pp. 323–331, Washington, D.C., 1854.

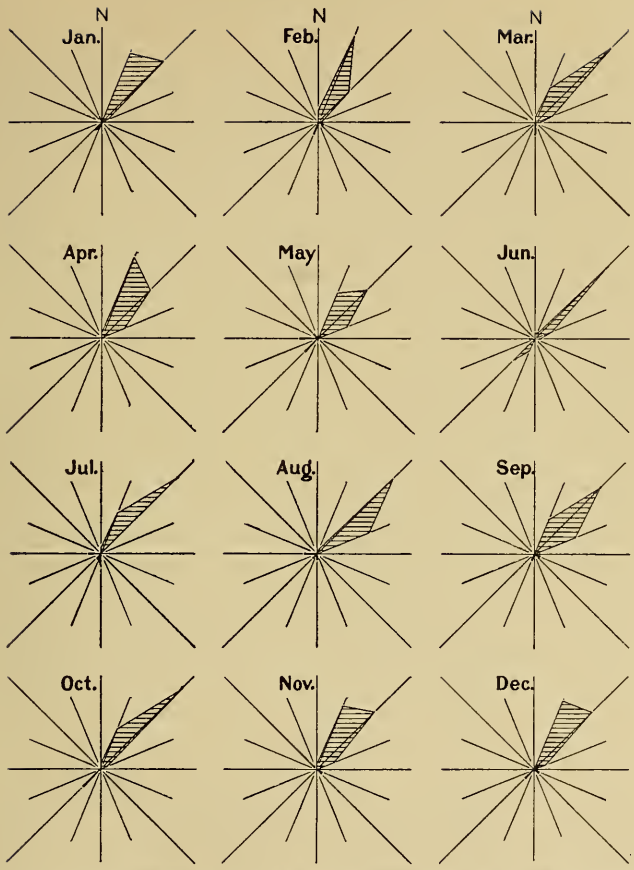


FIG. 18—Wind roses for Sucre, showing dominant winds for each month in 1915 save January (observations missing) which is replaced by January 1917. Constructed from data published in *Boletín del Observatorio Meteorológico* (S. J.), Sucre.

then rarely. It must be noted, however, that the movement of wind at higher levels over Sucre, as revealed by cloud observation during the same period, was most frequently from northwest to southeast.

Summary

In conclusion we may summarize the results of this examination of wind conditions. We have no records from the eastern slope, but it is generally conceded that the prevailing winds there are from the east or southeast, as they are over the ocean away from the coast. These winds, however, do not blow constantly; they prevail as up-valley winds throughout most of the day but are to some extent compensated for by down-valley winds at night. Over the western Andes and most of the Altiplano the main movement is from west and southwest. At Sucre it is from northeast. At Cochabamba southeasterly winds predominate, while the southwesterlies are next in importance. At La Paz the same is true—allowing for configuration. It would, therefore, appear that the Bolivian plateau draws air towards it and must consequently be a center of low pressure. The winds of Sucre and Oruro would seem to indicate that the kernel of this "low" is at about 20° S., over the great white salars. If this be so there must be a strong up-draught here, and the local cyclones of the plateau may take their origin in this area. The Cordillera Real appears to form a real barrier to air movement, although the easterlies succeed in penetrating here and there, as at La Paz. Lastly, if the anti-trades exist above this region they are probably not to be met below 6,500 meters.

Precipitation

Bearing in mind the average conditions of air circulation, we may proceed to consider the moisture it carries and the conditions of condensation and precipitation. With the barrier of the Eastern Cordillera thrown across its path, the trade wind, which has passed from the Atlantic over the lower portions of the continent, is forced to rise rapidly on the slopes. Moreover, in the southern summer these winds are reaching their goal—the vicinity of the thermal equator—in this latitude, and the air has an upward tendency on that account. The result of this is cloud formation and rain. The former—orographical—cause provides a

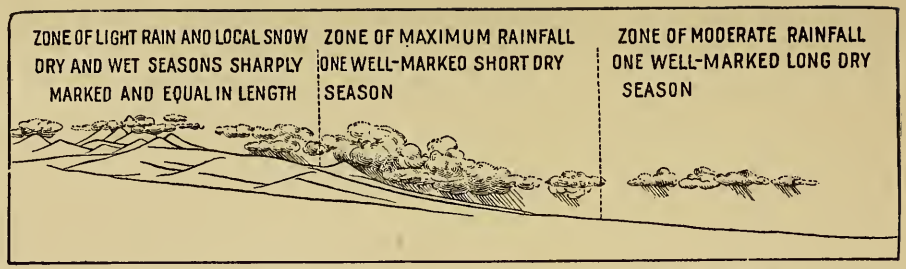


FIG. 19-A—Cloud types and rainfall belts on the eastern border of the Andes in the dry season, southern winter. The zone of maximum rainfall extends approximately from 1,200 to 3,100 feet elevation (366–955m.).

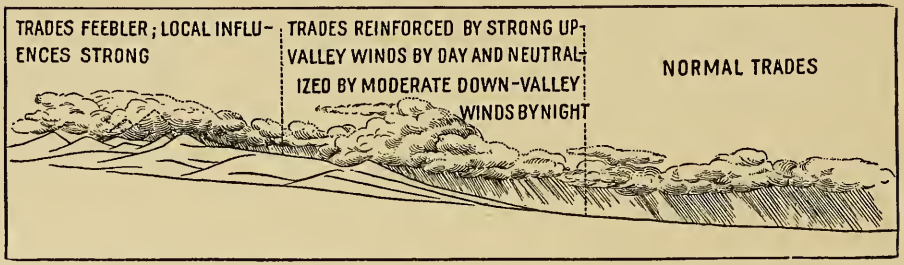


FIG. 19-B—Cloud types and rainfall belts on the eastern border of the Andes in the wet season, southern summer. Both figures are from Bowman: "Andes of Southern Peru," 1916.

reason for snow and rain on the cordillera in winter, while in summer both causes act together to produce much heavier condensation and precipitation on the mountains and over the plains of the Amazon basin. These meteorological conditions in the two seasons are illustrated by the diagrams (Figs. 19-A and 19-B) which, while they refer to a more northern portion of the Andes, still apply in our region, the only difference consisting in the longer dry period in the Bolivian mountains.

Figure 9 is a tentative map of the annual precipitation in the La Paz sheet area. It is based upon exceedingly meager data, discussed below, and upon deduction. But in spite of its problematical nature it will serve as a connecting link in visualizing the approximate physical conditions of life.

Precipitation on the Eastern Cordillera

No rainfall measurement has been recorded east of the Cordillera Real, and no isohyets have been drawn in that area. It is certain, however, that everywhere the annual amount is over 600 millimeters, and in the zones described as "maximum" the total is over 1,000 millimeters. From the geographical standpoint a very important feature of these eastern slopes is the cloud which is constantly formed and driven up the valleys to the passes, where it dissolves. This serves to reduce the temperature. It keeps the ground and the vegetation saturated and accounts for the very dense undergrowth of the *Montaña* forest. It makes possible the growing of fine coca and coffee. The cloudy area, which is represented by a stipple on the map, is somewhat reduced in the winter months (see Fig. 19). The importance of convection currents is indicated by the frequency of thunder and hail storms in the valleys. Occasionally the latter are so severe that fruit trees are stripped bare of leaves and fruit.

Two rainfall stations lie just on the lee side of the Cordillera, La Paz and Cochabamba, for which the mean annual rainfall is 538 and 462 millimeters respectively.[14] The precipitation at La Paz must be derived from air which continues to rise after over-

[14] These and other means are derived from Ernst Ludwig Voss, (85).

topping the mountains and so has still more moisture wrung from it. December, January, and February are the wettest months, and June is the driest (see Fig. 21). At Cochabamba we have seen that winds from the north and east are rare, and it is likely that much of the rain is brought by the southeast wind from over the wide lower plateaus of the Eastern Andes. The same is true of Sucre, which is farther east and receives 694 millimeters of rain. Here the wind, however, is northeast. The graphs for Cochabamba show two years with slight winter rain and two with practically none.

Precipitation on the Western Cordillera and Coast

Given an ocean and a prevailing on-shore wind striking a mountain range, the obvious result would at first sight appear to be a copious rainfall and well-filled rivers. And yet the Western Cordillera is very dry, and its piedmont is a desert. The solution of this enigma lies, of course, in the relative temperatures of sea and land. These are in strongest contrast in summer. At that season the wind from the warmer outer ocean is cooled in traversing the waters of the Humboldt Current and the still colder upwelling water of the shore. Fog, therefore, is common over the sea. The wind, still charged with humidity, is then forced upward on striking the low but steep coast range; but apparently these hills have absorbed sufficient heat to cause reëvaporation, for cloud rarely hangs over them at this season. The strong afternoon winds of summer, as they rise gradually with the land and are probably urged upward by convectional currents, form more and more cloud and at about 2,000 meters begin to form fog at ground level. Above this altitude there is more cloud in the sky, and rain or snow falls at intervals. But even here on the upper slopes of the cordillera the mountains are sufficiently warm to prevent regular or heavy precipitation. Figure 20 (A) and (B) illustrates the cloud conditions in summer and winter on the Pacific slope. It seems probable that precipitation is connected in some way with the mingling or contact of air currents from ocean and plateau, since on all rainy days at Arequipa between December

and March 1888–1889, wind blew from the northeast or north-northeast in the morning or evening at least. On Figure 21 the monthly rainfall for four summers at Arequipa is given, and the mean quantity for these is only 113 millimeters. The wettest period falls between January and March, the maximum being usually in February. Rainfall varies greatly from year to year, and it is probable that a longer series of observations would bring out the cyclic character of this variation. The virtual absence of rain in some years, as in 1888–1889, when less than 10 millimeters fell, makes the storing of water imperative for the success

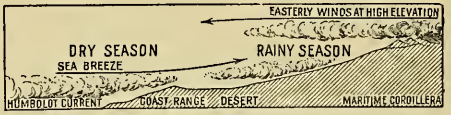


FIG. 20-A—The wet and dry seasons of the Coast Range and the Cordillera are complementary in time. The "wet" season of the former occurs during the southern winter; the cloud bank on the seaward slopes of the hills is best developed at that time and actual rains may occur.

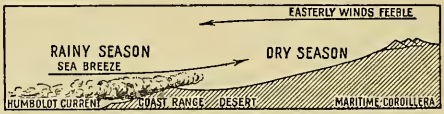


FIG. 20-B—During the southern summer the seaward slopes of the Coast Range are comparatively clear of fog. Afternoon cloudiness is characteristic of the desert and increases eastward. Both figures are from Bowman: "Andes of Southern Peru," 1916.

of agriculture.[15] Above the level of Arequipa precipitation is heavier and on the higher mountain groups is mostly in the form of snow or hail. In the upper basin of the Río Chili, which lies behind the line of high volcanic peaks, the mean rainfall is believed to be about 200 millimeters; and at Vinocaya, still farther north, it is 263 millimeters.

In winter, conditions on the Pacific slope are different. Then the winds from the ocean must carry a smaller amount of humidity. But as they traverse the cooler coastal waters some of

[15] See below, p. 102, and Figure 23.

this is condensed as cloud. Then on rising abruptly over the Coast Range the air gives up more moisture, and both cloud and rain are typical of these hills in late winter—a condition known as the *Tiempo de lomas*, by which is meant the season of rain on the lomas.[16]

While the foregoing description of climatic features in the coastal belt is true in general, there are certain exceptions which require mention. Indeed, it is the abnormalities of climate which make the most lasting impression on the inhabitants. We have seen that the only strong winds as a rule are from the sea; but in February, 1911, occurred a phenomenon which seems to be experienced periodically. A hurricane from the mountains developed in central Peru and extended southwards through 20 degrees of latitude. It followed a heavy snowfall in the cordillera and reached the lowland towns as a warm northeast wind bringing heavy rain and hail, flooding the valleys. Inundations caused havoc at Moquegua, Tacna, and Tarapacá. A still more notable phenomenon occurred in the Pampa of Tamarugal in January and February, 1885, when there were forty consecutive days in which rain fell continuously from 1 to 7 P. M. The direction of the wind in this period unfortunately is not recorded.

Precipitation on the Altiplano

On the Altiplano of Bolivia the most outstanding climatic variation is its decreasing humidity from north to south. This feature is abundantly proved by the southward succession of a large freshwater lake, Titicaca, through a salt lake, Poopó, to a group of salars in the southern part of the interior basin, which may indeed be regarded as a great evaporating pan. An attempt has been made to bring this out by the isohyets on Figure 9. These are supported by few instrumental records, which, however, are probably drawn from almost the wettest and driest portions of the plateau and are therefore specially useful. At Puno measurements are available for only one summer—No-

[16] The question of rainfall in this section is more fully discussed by Bowman, (8), Chaps. 9 and 10.

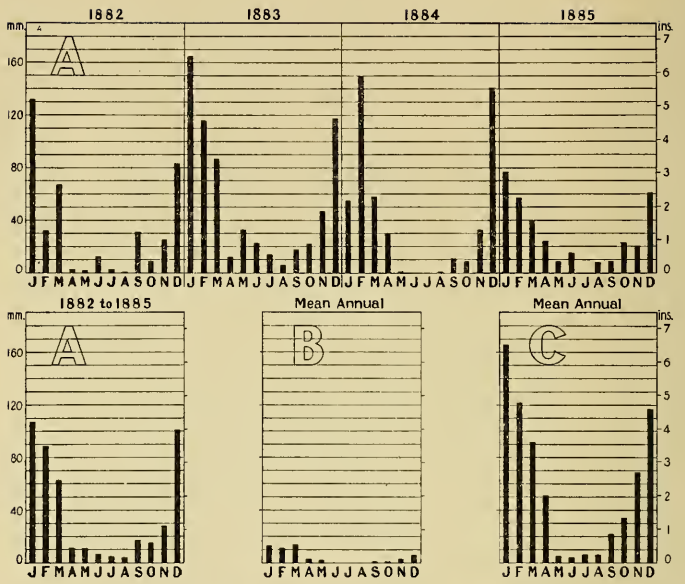


FIG. 21—Graphs showing monthly precipitation: A, at Cochabamba, 1882–1885 and means for that period; B, Oruro, means for 1885–1888; C, Sucre, means for 1883–1897; D, La Paz, Aug. 1899–Oct. 1901 and means for 1898–1902; E, Arequipa, Nov. 1888–Mar. 1890 and Jan. 1902–Nov. 1903. Constructed from data published as follows (numbers refer to App. C, Bibliography): A (89); B and C (88); Mar.–Apr. 1898; D (88) and, for means (85); E (87).

vember, 1888, to March, 1889, and during these months rainfall was approximately equal, giving a total of 737 millimeters. This is almost three times the annual rainfall recorded in the same period for Vinocaya, which lies higher and farther west. It apparently indicates the importance to the western shore of Titicaca of the off-lake winds already mentioned. The country bordering this lake is almost certainly the wettest section of the plateau. La Paz with 538 millimeters of rain is in a special situation, dealt with above, but it gives some indication of conditions on the eastern edge of the plateau as far south as latitude 17°. Oruro with only 54 millimeters of rain is clearly in the arid portion of

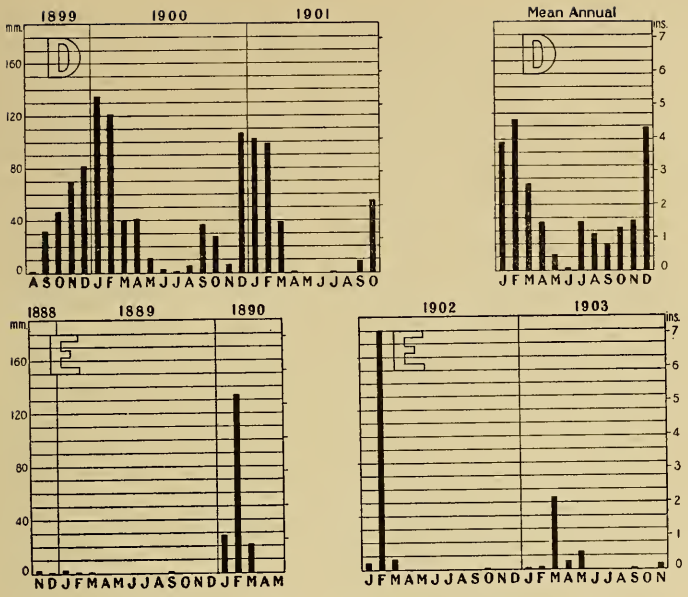


Fig. 21 continued. For description of figure see opposite page.

the plateau; and the great difference between its annual quota and that of Sucre, with a mean of 694 millimeters, points to a westward decrease which is probably gradual over the higher plateaus and sudden at their western escarpment.

It is impossible to say whence comes the moisture which is precipitated on the Altiplano south of Titicaca. Precipitation in the form of snow, hail, or rain is nearly always associated with violent winds, presumably connected with the local depressions referred to above. It takes place in the afternoon or night during the summer and rarely in the forenoon.

The entire area of the La Paz sheet save the coastal hills receives the bulk of its rain in the summer months, the month with the highest precipitation for most places being February; but in

occasional years the maximum comes as early as November. On the Altiplano and Maritime Cordillera there is a progressive shortening of the rainy season from north to south, corresponding to the increasing aridity in that direction. The rains do not as a rule start suddenly but are heralded for at least a month by an increase in the amount of cloud, and in the same way a cloudy month follows, after the rains have ceased.

A paper published when the above chapter was in proof indicates that some of the statements regarding precipitation on the eastern slopes of the Andes require modification. Rusby, discussing botanical results of a journey over the Quimsa Cruz Cordillera to Quime and thence to Espia on the Bopi by the trail marked on the map, describes[17] a number of drought resisting elements in the vegetation of the lower slopes (below 3,000 meters) in all but certain exposed situations which are known as "rainbelts." This would indicate that the ranges to the east are somewhat higher than they are shown on the map, and that the local contrasts in precipitation conditions require to be more emphasized. It would seem that in these interior valleys there is a well marked dry season in winter.

[17] Henry Hurd Rusby: Report of Work on the Mulford Biological Exploration of 1921–1922, *Journ. New York Bot. Garden*, Vol. 22, 1922, pp. 101–112.

CHAPTER VI

DRAINAGE, WATER SUPPLY, AND SOILS

With our knowledge of the rocks, land forms, and climate we may assert with confidence that the great majority of the streams shown on the La Paz sheet west of the Eastern Cordillera are intermittent in character and contain water throughout their whole course only in the wet season. The only part of the map in which surveyors have noted the nature of rivers—permanent or intermittent—is the Western Cordillera and piedmont in Chile. For the rest of the territory it may be said in general that the permanent streams include all those which rise in the Eastern Cordillera north of the latitude of Cochabamba and the larger watercourses to the south of that; on the plateau they comprise the Desaguadero and the larger rivers which rise in the Western Cordillera such as the Blanco, Mauri, Cosapa, and Lauca. But even these are likely to dry up in their lower reaches in dry seasons. Of the rivers which flow to the Pacific all which drain the main crest of the Cordillera are permanent in the greater part of their courses, and a few have permanent outflow to the ocean. All other rivers shown are wet-weather streams.

Throughout the entire territory the contrast between summer and winter is very great. In the Yungas of the Eastern Cordillera (see Fig. 29), the large daily precipitation of summer and the waters from snowfields keep the valley bottoms filled with swiftly flowing rivers. Waterfalls are numerous, and the soil of the steep hillsides, sodden after weeks of rain, breaks loose and causes landslides which leave great scars of bare rock. It is in this season that the débris of the winter's weathering is removed by the scavenging torrents, and the work of valley cutting by rivers must be virtually concentrated in the summer months. Throughout the entire rainy period travel in the Yungas is difficult or, where trails follow valley bottoms, impossible.

On the Altiplano the slopes are relatively slight, and the summer precipitation is carried off much more slowly. Over vast tracts the bare soil is porous, and the first falls of rain are rapidly absorbed; but after recurrent storms the water fills the steep-sided gullies and accumulates on the lower flat lands such as those to the north of Lake Poopó, there to be slowly dissipated by evaporation.

In the Maritime Cordillera the rivers are nourished by snow and rain but not by glaciers; and, in proportion as streams are snow-fed, their regimen is regular. If we may judge from the flow of the Chili at Arequipa those of the Peruvian section derive their water almost entirely from rain. Figure 23 shows the flow of the Chili for five years in cubic meters of water per second. Figure 21 (p. 93) gives the monthly rainfall for two of those years at Arequipa. The general agreement of the two figures is at once apparent, and if rainfall statistics were available for a station farther up in the Chili basin it is probable that a full river bed would be seen to follow immediately upon heavy rainfall there. The river graph shows almost complete absence of flow from April to November or December; and in this period as a rule no rain falls. These western rivers are all torrential, the slope and absence of forests contributing to the rapidity of the run-off.

Snow and ice as a source of water are surprisingly unimportant considering the great altitude of the mountains. The snow line in the Andes is at its highest—about 6,500 meters—not at the equator as might be expected but at 25° south, and throughout the whole of the sheet area it is abnormally high. This anomaly seems to be due ultimately to the existence of the wide plateau between the cordilleras, but it is not clear to which of the meteorological elements we must turn to understand fully the reasons for the exceptional height of the snow line in these latitudes. In the Western Cordillera in this section there are no glaciers, and permanent snow exists only on the highest peaks of the southern part —Tacora, Huallatiri, Sajama, etc. It is absent from Misti, and nearly absent from Chachani. The snow line is in the neighborhood of 6,000 meters. On the Eastern Cordillera it appears to be

about one thousand meters lower. On the northeast side snow seems to lie permanently down to 5,100 or 5,200 meters, and on the southwest side to 4,800. As previously mentioned, there are still numerous glaciers in the cirques of these mountains; and the fronts of these of course are found well below the snow line. In the southeastern part of the sheet reliable information is lacking regarding the highest summits, but no permanent snow is believed to exist there, although in the Ice Age there must have been considerable snow fields to nourish the glaciers whose tongues reached down to the Altiplano. It is at least certain that no glaciers remain, and this is apparently sufficiently accounted for by the lower precipitation on these interior mountains as compared with the front ranges.

Water Supply

Enough has been said to emphasize the great water resources of the Cordillera Real and the front ranges to the south of it. There such disadvantages as exist arise from the excess of water interfering with communications. But, unfortunately, in this well-watered region the topography is unfavorable to dense agricultural settlement. The bulk of the Bolivian population lies west of and just outside the zone of abundant water (see Pl. I), and the question of extending the cultivated area in the future is in part bound up with the possibility of diverting water from these mountains. The former glaciation of these cordilleras is responsible for the existence in them of a large number of rock basins near the summit, many of which contain permanent lakes; and, given sufficient capital, such basins could be made the nucleus of increased water supply for the drier valleys and the eastern fringe of the Altiplano. Again, nature has endowed the region with all the physical requirements for hydro-electric energy. Many of the mines already utilize water power for their own purposes; and it would seem that the lack of funds and of industrial life alone delays its much wider application. In Bolivia demands for domestic water supply cannot be called exacting, and it is only in the larger towns that any effort has been made to sub-

stitute a modern system for the common well and the often distant stream bed. La Paz now obtains its water by aqueduct from a glacial lake, artificially enlarged, 15 miles (25 km.) north of the city. Oruro has a pipe line leading water westwards from a reservoir in the valley above Sepulturas. But the supply falls far short of the needs of a modern town, and water has to be carried from a number of public fountains. A project, however, has been approved by which water will be led to Oruro by a canal of 35 kilometers from the Desaguadero. In Cochabamba the domestic supply is piped from the Cerro Tunari, where there is also a power station. The city has further had to solve the problem of putting a stop to the periodic damage due to the River Rocha overflowing its banks and taking to the streets. This work has been accomplished by diverting part of the river water four kilometers upstream and carrying it in a tunnel through a ridge to a natural depression lying southeast of the city, where it is used for irrigation.

Hydrography of the Altiplano

As has been mentioned (p. 23), the Altiplano is drained in general from northwest to southeast. Lake Titicaca, of which the greater part lies north of latitude 16°, has an area of about 5,100 square kilometers and is the largest lake in South America (about one sixteenth of the size of Lake Superior). The lower lake is shallow, but a large part of the main lake is over 200 meters deep (deepest sounding 272 m.), so that the volume of water is very considerable. This water, which is fresh save in the shallow lower lake where it is slightly salt, is derived in the main from the Cordillera Real, although the area tributary to the lake is much more extensive on the west and northwest. All observers are agreed that the average contributions to the lake very greatly exceed the amount of overflow by the Río Desaguadero. But the immense evaporation which takes place over its surface, as on the plateau to the south, would appear sufficiently to account for this. The progressive though slight reduction of Titicaca in area and depth in historical time may be mentioned. There is also a slight

annual fluctuation in level (from one to two meters) following the seasonal precipitation, and it is probable that in addition the average level exhibits a cyclic oscillation in conformity with the supposed seven-year cycle of rainfall.

The Desaguadero (see Fig. 2 opposite page 23) when in flood is estimated to carry eight times the amount of water which flows at its minimum, this contrast being produced in part by the changes in lake level and in part by the periodic contributions of its tributaries. These contributions themselves are also thought to vary according to the season in the proportion of eight to one. The Desaguadero down to Nazacara is practically an arm of the lake, relatively deep, falling only six centimeters per kilometer and having a surface velocity (in flood) of only 23 centimeters per second. At Nazacara the river crosses a threshold, and down to Concordia, just above its confluence with the Mauri, it has a slope of 17 centimeters per kilometer. At low water this stretch is everywhere over 90 centimeters deep. From this point to La Barca (northwest of Oruro) the river has a nearly uniform fall of 2.25 meters per kilometer, and in two places (La Barca and near Ulloma) it crosses sandstone thresholds with only 55 centimeters of depth at low water. But, in spite of the increased fall, the average velocity in this section is less than above Concordia, since the stream bed is wider. Below La Barca the fall is only 25 meters in 110 kilometers. The detailed examination of the river made in 1903 by the geographical service of the Bolivian army, whose observations are summarized by Sever,[1] has shown that the losses by evaporation during the low-water period are slight but appreciable at high water (i. e. in summer) and that the average flow of the river is about 20 cubic meters per second in low water and 170 cubic meters in high water. The river was navigated up to the date of the opening of the railway to Corocoro by flat-bottomed stern-wheel boats as far downstream as Nazacara, and, thence southward to the ore docks, box-like boats of steel were poled or towed. It is estimated that by dredging navigation could be extended to Lake Poopó without great difficulty.

[1] Jacques Sever, (96).

Lake Poopó has an area of about 2,530 square kilometers and is everywhere shallow (deepest sounding 3.95 m.). These figures refer to the low-water period (winter); in summer, although there is probably only a very slight rise in level, the area increases considerably, as the shores are very low. Lake Poopó may be thought of as an immense evaporating saucer. It receives from the Desaguadero at low water 20 cubic meters of water per second and perhaps 2 meters from other streams, while about 6 cubic meters run off at its outlet. The lake, then, receives a daily net increase of 16 x 60 x 60 x 24 = 1,382,400 cubic meters. This divided by the superficial area gives the amount by which the surface would rise daily, viz. 0.00054 meter; and, as the lake is more or less in a state of equilibrium, this figure represents approximately the daily amount of evaporation. In the high-water period—December to February—the intake from the Desaguadero is about 170 cubic meters per second and the outflow about 120 cubic meters; but, as the area for the lake at that period is unknown, it is fruitless to attempt to calculate the evaporation. The outflow by the Lacahahuira appears to be permanent, but in the section nearest the lake no well-marked watercourse is developed—the water disappearing under the sand, and several explorers who have encircled the lake reported that it had no outlet.

The water of Poopó is brackish and undrinkable. A sample taken by Neveu-Lemaire was found to contain over 23 grams of salts per mille, nearly 17 being common salt and over two each being sulphates of sodium and calcium. The Salar de Coipasa is intermittently flooded over wide stretches by the Lacahahuira and other streams, but the only permanent water now lies in the residual lake or swamp in its northwestern hollow, which must be highly saline. The numerous small settlements over the Altiplano depend for water upon wells, springs, and streams; and it must be remembered that the water requirements of this population are very small.

Hydrography of the Pacific Slope

On the Pacific slope water is of the highest importance. While it is the absence of water which has permitted the accumulation

FIG. 22—The end of a river on the piedmont. The flow ends in front of the horseman. A view typical of the numerous streams of the coastal lowland which reach the ocean only on the rarest occasions. The river has slightly incised its valley in the piedmont deposits.

of the nitrates, the most valuable resource of the coast lands, it is the ability to get water which determines the distribution of population in general. As has been pointed out, precipitation on the Maritime Cordillera takes place for the most part only along the higher summits of the chain, save in the short rainy season when it extends to the seaward slopes but not on to the piedmont. It will be readily understood, then, that only those rivers which possess a considerable gathering ground amongst the high peaks have sufficient content to carry them to the ocean as permanent streams. These rivers are, from north to south, the Tambo, Locumba, and Sama, while the southern Vitor in virtue of exceptional springs is also permanent in its whole valley. The next group consists of rivers which have smaller basins, or have their headwaters in the zone of annual rains, and are permanent in their upper courses but reach the sea only in summer. It includes the Vitor, Moquegua, Lluta, Azapa, Camarones, and Camiña; and some of these are permanent to within a few miles of the coast. In the south the Aroma and Tarapacá are important streams, but they do not reach the sea; they are in fact the first of a long series of rivers extending more than six degrees to the south which lose themselves in the desert of Atacama (see Fig. 22). In addition to these many stream courses are shown on the map which carry water only most intermittently. Of all the rivers of the Pacific slope the Tambo has by far the largest basin, and it alone carries large quantities of water to the ocean.

The Peruvian Corps of Mining and Water Engineers as well as Chilean government engineers have made detailed examinations of the regimen of a number of rivers with the view of improving the water conditions in the valleys, and from their reports it is possible to gain some idea of the real nature of the streams. The Chili, already alluded to, is one of the two main branches of the Peruvian Vitor, and it is specially important because it waters Arequipa and its densely peopled agricultural neighborhood (see Fig. 35). It may be taken as typical of rivers which have a moderately sized basin in the heart of the Cordillera with a high summer rainfall but probably with no great accumulation of

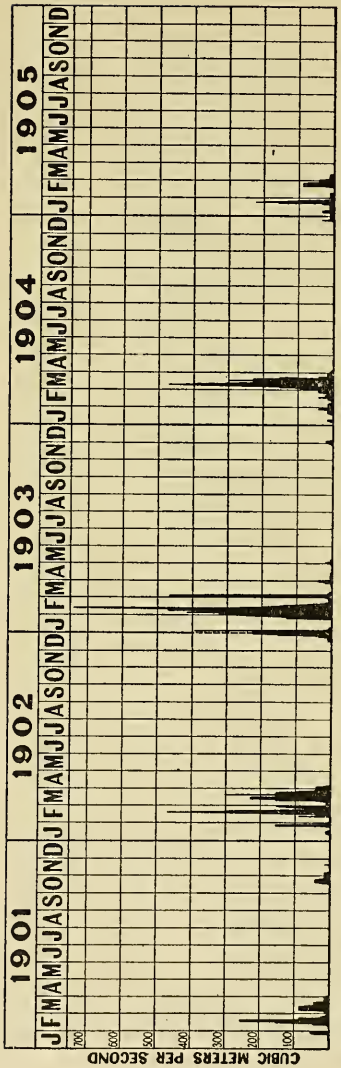

1901
1902
1903
1904
1905
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
700
600
500
400
300
200
100
CUBIC METERS PER SECOND

FIG. 23—Graph representing the flow of the Río Chili at Arequipa throughout a five year period. Generalized from the graph of H. C. Hurd, (99).

snow. Its erratic nature is clearly illustrated in its curve of flow for five years (Fig. 23). The average annual flow at Arequipa is 729,000,000 cubic meters, which is about half the quantity passing by the Desaguadero into Lake Poopó; but from its extreme irregularity it is only possible for the farmers to use a mere fraction of this water. In 1906, when the investigation was made, only 2,600 hectares were under irrigation about Arequipa (and 8,000 in the entire Vitor basin), and much of this suffered damage in dry seasons. Recommendation was then made that a dam be built at a point 35 kilometers above Arequipa to store up to 24,100,000 cubic meters annually, which would be sufficient to extend the irrigated area by 1,145 hectares and supply ample water throughout the four driest months.

In each of the river basins examined the conclusion was the same. Great improvement could

be made in agriculture by regularizing the flow of the streams. In some cases the solution is simple, as there are good sites for dams which would affect the whole region below; but in others —as in the Moquegua—this is out of the question, and smaller local improvements are all that can be attempted. These include, first, the building of small tanks to catch casual rainfall; secondly, the construction of filtration channels to concentrate the slowly flowing water in the alluvium of valleys—this is an ancient method but has fallen into disuse, although one such channel still collects the water supply for Moquegua town—thirdly, the improvement of the irrigation channels to prevent waste; and, lastly, the pumping of water from the deeper valley deposits—a method already employed with success on some of the larger haciendas, as in the neighborhood of Ilo.

In the last sixty years a number of more ambitious projects have been examined with a view to increasing the flow of one river at the expense of another where the demand for water is smaller; while other proposals have been made to carry waters to irrigate entirely new land. These last are the more obviously impracticable, as they consist in raising water from the deep valleys on to the higher flat lands flanking them. Two examples may be given: first, to irrigate the land about Cachendo on the Southern Railroad of Peru by water from the Tambo; and, secondly, to raise the water of the Locumba to irrigate the pampa at Sitana. While practically all water of the flood season on the Pacific slope if husbanded could be utilized in irrigating hitherto uncultivated land, it seems clear that this irrigation must be limited to the valleys themselves. Of the diversion projects it may be of interest to mention a few, although it is doubtful if any of them will be fully carried out. The Tambo has more water than can be utilized in its basin, whereas the Moquegua with its small basin is one of those most demanding increase. It was proposed to tap the marshes at the head of the Río Omalso and carry the water through the divide to the Río Chilligua. Another project was to draw the water of the Lago de Istunchaca, which is intermittently tributary to the Locumba, through the

divide and into the Río de Torata. Again, there have been various similar projects for augmenting the supply of several of the more southerly rivers, some of them at the expense of the streams draining eastward to Bolivia. Thus the Camiña was to be augmented by water from the southern headwaters of the Camarones, which in turn should receive compensation by means of an aqueduct from the Lake of Surire—a basin on the eastern side of the main crest of the mountains but without a permanent outlet. It was proposed to add to the Aroma's resources by tapping the Mauque, but this would presumably have to be a matter of arrangement with Bolivia; while there have been schemes on foot since 1794 to increase the supply of the Tarapacá by the waters of two small lakes of Chuncará which lie on the divide itself.

The most ambitious of all diversion schemes has actually reached the construction stage, and, as it will divert water from Bolivia, it has aroused violent opposition from the Government of that country. I refer to the plan to divert the upper Mauri and by bringing it over the saddle followed by the Arica-La Paz railroad to turn its waters into the valley of the Palcota. By this project a Chilean sugar company at Tacna hopes to be able to irrigate a large stretch of land southwest of that town. For over half a century Tacna has been seeking to increase her water supply from the high Andes and by 1870 had taken the first step by the construction of a canal, which is shown on the map, from the Río Uchusuma, a tributary of the Mauri, through the pass above Bella Vista by means of a tunnel to the Quebrada Huanacagua. This canal, which is 52 kilometers long, was supposed to give a flow of 3,000 cubic feet of water per minute but in fact only furnished about a quarter of this amount.

The greater canal above referred to starts on the upper Mauri below its confluence with the Río Chiliculco in latitude 17° 30′, whence it is to follow the right bank of the Mauri, increasing in capacity as it goes, so as to accommodate the waters of right bank tributaries. Then, reaching the Caño valley by a low saddle, it will pass southward and along the north shore of the Laguna Blanca to the continental divide; and thence, like the Uchusuma

canal, south of the Cerro de Tacora, crossing the Río Azúfre in a siphon and the Huailillas pass in a tunnel, it will empty into the Palcota valley. This canal when complete will be about 150 kilometers in length; and it is estimated that it will bring to the Pacific slope from the drainage of the intermontane basin over 3,000 liters of water per second. Bolivians look forward with much apprehension to this loss of water. Their advocate in the matter, J. Aguirre Achá, states[2] that the valuable pastures—especially suitable to the alpaca—of the upper valleys will be greatly diminished; that the resources of fish in the Mauri—said to be considerable—will be much reduced; and that it will become impossible to utilize the Mauri for hydro-electric power. This refers to a project by which the water would be led fifty or sixty kilometers and then with a head of 100 meters would produce some 4,000 horse power to be used by the mines of Corocoro. The damage which would ensue to the Desaguadero is also adduced in opposition to the diversion scheme. Navigation, contemplated as the aim of a project of canalization, would render it impossible, and the plan of supplying water from the Desaguadero to Oruro would be interfered with.

While the chief aim of engineers in regularizing the flow of the rivers is to improve conditions of agriculture, such works would also tend to reduce the damaging effect of the sudden floods to which all the valleys are subject. The Tambo valley with its greater water content perhaps experiences the most serious devastations of this character, but there are records of great floods in the Pampa del Tamarugal in the mid-eighteenth century and in 1819, 1823, 1852, 1868, 1878, and 1884.

The water conditions in the Pampa del Tamarugal are interesting, and their relation with the nitrate formation has already been referred to. While the mountain streams disappear on or near its eastern border, the rim of coastal hills acts like a dam and enables their waters to be conserved in the subsoil of the pampa. The presence of this water table makes it possible to concentrate a large population in the nitrate fields by furnishing a supply to

[2] José Aguirre Achá, (97).

all grades of wells, some of which, however, do not give drinking water. For instance, the well at Dolores produces 150,000 liters in 24 hours, but the water is brackish and has to be treated with sodium carbonate before being fit for use in locomotives. At various points on the pampa the removal of the salt crust is sufficient to lay bare the water table and to permit cultivation in *canchones*, of which more will be said.[3] It seems, however, that, as a rule, these perforations of the crust soon drain the local supply, and the cultivation is therefore transitory.

Enough has been said to show that the waters of the Pacific slope are barely adequate to supply the present agricultural needs of the coast lands and that any amelioration of water conditions will be undertaken in the interests of the farmer. It is, therefore, unlikely that any large development of water power will take place; but it may be noted that sufficient energy has been harnessed in the Río Chili to provide Arequipa with light and car service.

The domestic urban supply of water is primitive nearly everywhere. Apart from isolated springs on the mountain slopes such as those which provide ample irrigation for the villages of Huasquina and Zipiza (northeast of Tarapacá), the bulk of the inhabitants draw their water from streams or from water holes in otherwise dry stream beds. The condition in general is the same as it was at Tacna when Orbigny found[4] that the villages had water for five days and the town for two days. In the town, as soon as the church bell announced the arrival of the flood, everyone rushed to the river bank with vessels of all descriptions for the household supply. After two hours the water was turned into the gardens, whither all repair to direct the distribution of their allotted measure. The coast itself is very badly endowed with water, and the improvement of the supply of Pisagua by a pipe line from a well of the finest water at Quiuna on the Tiliviche has long been contemplated. The Arica-La Paz railroad could not be worked were it not for the pipe line nearly 140 kilometers long

[3] p. 175.
[4] Alcide d'Orbigny, (29), Vol. 2, p. 368.

constructed all along the railway from a point 12 kilometers south of Humapalca to bring water from the upper valley of the Lluta.

Soils

Soils are classified as young, mature and old, indicating a cycle of development which takes place slowly in arid lands and more rapidly where the rainfall is higher—the solvent action of water favoring the chemical changes essential to soil development. The process goes on especially fast where high rainfall is combined with high temperatures, this combination leading to great organic activity. We should, therefore, look for young soils alone throughout the greater and dry part of the area and expect to find older soils on the eastern slopes of the Andes. Topography, however, enters into the field, because it is necessary for soil to remain undisturbed for long periods if it is to advance to old age. Now we have seen that the moist region, the Yungas, is dissected by numerous deep and steep valleys and that only in the upper and cooler zone are there any considerable tracts where the slopes are gentle. We may, therefore, conclude in general that soil development on the moist slope of the Andes never advances very far before the soil is removed by erosion and carried off to the plains but that on the small tracts of gentler slope in the upper zone soils may reach maturity.

On the lower forested slopes, in parts where, for any reason, denudation is less rapid, the dense carpet of mosses is probably underlain by a *podsol*, a light-colored soil in which various mineral constituents have been leeched and redeposited deeper down. But the terracing and trenching in the belt of coca cultivation, where the forest has long been cleared, has almost certainly led to a complete mixing of the podsol and its substratum.

Generally speaking mature soils are the most valuable for agricultural purposes, while very young soils have not yet been sufficiently comminuted for their mineral constituents to be available for plants in any high degree. An exception to this, however, is found in the alluvium of the lower parts of valleys. In our region such soils are found in the valley oases of the desert and

in basins such as those of Arequipa and Cochabamba. The latter has the special advantage of being watered by well-nourished streams draining heavily glaciated plateaus, and these milky streams deposit a fine silt derived from the glacial detritus.

In the coastal desert it may be said that soil does not exist, the surface consisting of rock fragments, grit, and sand graded only by the action of the wind. (Fig. 22). In the Lomas the seasonal moisture of the *garúa* would lead to the formation of a true soil; but here the slopes are steep and development can never advance very far. The same is true of the slopes of the Western Cordillera above the desert zone. On the Altiplano, geological formations or their detritus are barely concealed by real soil save in hollows, where accumulation is possible; and even in these, in all the southern part, alkaline deposit frequently renders the soil unfit for cultivation. The chief exception to this is the alluvium of the Desaguadero valley and the neighboring expanses, periodically inundated, where the permanent vegetation has produced a heavy black soil. The so-called red soil of the western Altiplano in most cases is probably not a soil at all but merely disintegrated rock derived either from the sandstones or the andesitic lavas of the Western Cordillera.

A remarkable example of rapid soil movement in the Yungas has recently been described by Rusby (see footnote on page 94). A field of bananas at Cañamina has for years been observed to be on the move down the steep slope of the valley side. A reliable resident engineer stated that ten years ago the field was far up the slope and at least 300 yards distant horizontally from its present position. The patch of soil composing the field apparently moves as a unit, since the growth of the plants has not been interrupted.

CHAPTER VIII

THE NATURAL VEGETATION

The ancestors of plants which go to make up the different types of vegetation in the region have sprung from widely different origins, amongst them the pre-Andean South America and Antarctica—formerly connected with America, while Central America and also Western North America have contributed their quotas. The building up of the flora of today does not concern us in its detail; it has been reviewed in appropriate works.[1] But we may note that of past events the two which have had the most profound effect on the present composition of the flora are the (late Tertiary) upheaval of the Andes and the Ice Age. The upheaval of the high Andes had the effect of producing a dry climate in place of a relatively moist condition in the coastal zone and so changed the earlier vegetation from a mesophytic to a xerophytic or drought-supporting type. It thus put a stop to further immigration of Antarctic species, on the one hand, and of moisture-loving plants from the north, on the other. The onset of the first Quaternary glaciation with its lower snow line caused the depression of the mountain flora which has left its traces well below its present normal limits.

The most outstanding division of vegetation in the La Paz sheet area is that between the forests of the northeast and the much greater areas of scrub, grass, and other humble types of the south and west. This is a distinction which has struck every traveler; but it requires the discrimination of a practiced observer to delimit the subdivisions of these major vegetations; and, while the minor divisions are less striking, they are none the less illuminating, for they furnish in every case a sure index of local climatic features; and, moreover, the zones of natural vegetation correspond to the habitats of the various cultivated plants. In the

[1] August Weberbauer, (103) and Karl Reiche, (102).

following description of the vegetation the climatic relationships will be dealt with, and the economic plants will be mentioned, while the special features of their cultivation are reserved for another chapter.

In the sketch map of the natural vegetation (Fig. 24) nine types are shown, four occurring mainly on the Pacific slope, two entirely on the Atlantic slope, and three on the high cordilleras and intermontane plateaus. Most of them are formations which reach far north or south of our region with but little change.

Vegetation of the Lomas

The lomas, or hills of the coast, are characterized, as we have seen, by a damp season in the southern winter, the moisture being derived from the fog banks prevalent at that season. There is then a typical "lomas vegetation" that lies dormant throughout nine months, during which the lomas appear as a desert, but after

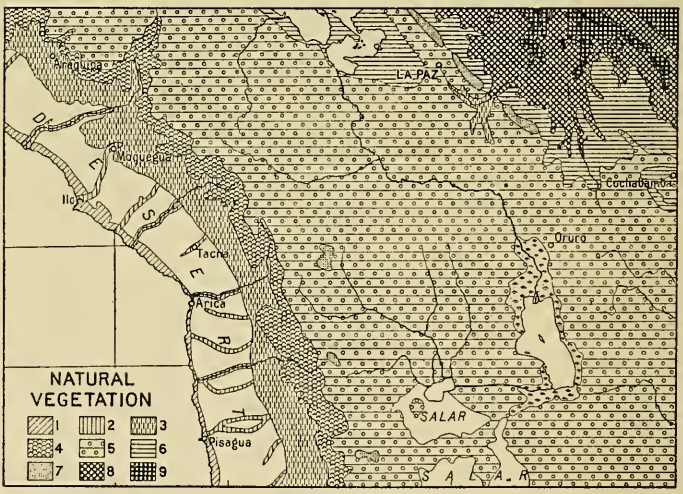


Fig. 24—Distribution of Natural Vegetation: 1, Lomas vegetation; 2, Stream-bank oases; 3, Succulent zone; 4, Tola zone; 5, Puna; 6, Grass steppe; 7, Dwarf vegetation (Antarctic type); 8, Ceja de la Montaña (forest); 9, "Montaña" (forest).

mid-winter puts on a thin veneer of verdure. This consists of a rather open cover of herbaceous plants both annual and perennial, including many bulbs and tubers as well as mosses and lichens in thick clumps. The amount of vegetation varies from year to year according to the quantity of moisture in the soil, so that in some winters only the hill crests become green, while in others the green mantle extends down to the landward foot of the coastal ridges; and this variation is keenly observed by the herdsmen of the valleys, who drive their flocks to the hills each spring. The dividing line between vegetation and desert, however, is not always clean-cut. The line drawn on the map represents the widest extent of the lomas formation. One of the most striking features of plant growth here is that, despite the proximity of the desert, the great majority of species possess no equipment for retarding evaporation. This is not necessary, because of the small amount of sunshine in the "lomas season." This feature, naturally, is less marked on the sandy margins of the zone. Along the occasional stream banks there is an evergreen zone of bushes such as willow and acacia, climbing plants, and reeds.

That this vegetation made a very clear impression upon the first Spanish inhabitants is evident from the following statement, made in the sixteenth century.[2] "In these plains, between the mountains (*sierra*) and the sea, there runs a cordillera that is quite high, which the Spaniards call *lomas*, where the season of dew, or *garúa*, produces much vegetation, with great freshness and a great variety of flowers and roses of many colors and forms. The Spaniards make use of these lomas in the season referred to for their (horned) cattle, since there is then much very good pasture; but when the dew fails, in eight days it is dry, without a sign to indicate that there had been plants or flowers; and any cattle which, because of greed or because of neglect on the part of their owners, delay in getting out, perish of hunger and thirst."

The more or less continuous clouds of the winter months on the Peruvian Lomas are replaced on the coast south of Arica by

[2] Ramirez: Descripción del Reyno del Perú (1579), quoted in "Juicio de Limites," Vol. I, p. 286.

fogs (*camanchaca*) which lie on the hills and cliffs only by night and in early morning. Moreover, they are best developed in autumn and early winter. It follows that the Lomas vegetation is much less typical of this coast—being found well developed only in the shady gullies; elsewhere cacti and similar water-holding plants form the bulk of the vegetation. In other words the desert approaches more nearly to the coast here.

The Desert

The deserts of this part of the Pacific coast lands, while not so completely devoid of life as parts of the Sahara, are yet sufficiently barren to merit the name in all but a few weeks of the moister years, when a number of humble flowering annuals spring up; while in the parts which are either very sandy or very salt almost the only plants are the Distichlis grasses which are furnished with long, creeping rhizomes and in places succeed in binding the sand. The southern part of the desert zone derives its name—Pampa del Tamarugal—from the tree (*Prosopis tamarugo*), a small prickly mimosa, of which there were formerly large numbers to the east of the salars bordering the nitrate fields. These trees and the Distichlis grass, which here grows in large tufts of over one meter in height, derive their moisture mainly from the ground water which is the special feature of this pampa. The great quantity which exists of dead tamarugal stumps have been mentioned as evidence of a drying climate. The living trees, as well as the stumps, are used for charcoal making in the nitrate fields, so that the species is being gradually exterminated from the region.

The few river valleys are the oases in the desert. Their natural vegetation includes trees—the *chañar* (*Gourleia decorticans*), the *molle* or pepper (*Schinus molle*), and a willow (*Salix Humboldtiana*)—as well as a number of shrubs. Some of the latter attain large size as in the Camarones valley, where bushes have been reported four meters high and ten in diameter. But the natural vegetation in these strips has been largely replaced by irrigation agriculture.

The desert and Lomas zones apparently include only one native plant of great economic importance, the chañar tree whose fruit—brown and globular—is eaten by man and beast, while it also forms the basis of a sirupy beverage. Parts of some of the bulbous plants were also used as food in former times. But since the Spanish Conquest and even before it a great variety of products introduced from other zones or from Europe have been successfully cultivated by irrigation. Thus the hot, dry climate has proved admirable for the raising of every sort of fruit and vegetable from the Mediterranean countries—such as olive, fig, pomegranate, mulberry, quince, cherry, melon, citrus fruits, and the grape vine, from which several excellent wines are made; in a few spots are found rice and sugar cane, which supplies alcohol as well as sugar; wheat and barley are the chief grain crops, but there is also much maize—introduced before the Spanish period; and, lastly, large quantities of alfalfa (lucerne) and honey grass (*pasto de miel*) are raised for fodder and exported.

Vegetation of the Western Cordillera

On the Pacific slope of the Cordillera reliable botanists have determined the vegetation zones about latitudes 16° 30′ and 19°, and the altitudinal limits for the two sections agree well; but for the area between, such information as exists places the limits of the zones from 1,000 to 2,000 meters lower—a result which clearly requires further investigation. In drawing the vegetation map, therefore, the intermediate data have been neglected pending further inquiry. Assuming, then, that the two sets of observations above mentioned are typical of the entire slope, the zones are approximately as follows:

(A) the Succulent Zone:

From 1,900 meters (in the south) and 2,200 meters (in the north) to 3,600 meters (in the south) and 3,400 meters (in the north). This is a zone which receives rain in the late summer (January to March) but which is subject to intense evaporation throughout the other nine months. The vegetation is therefore adapted to resist drought, and succulents enter largely into its composition.

(B) the Tola Zone:
From 3,400 meters (3,600 meters in the south) to about 4,200 meters.
This zone is somewhat moister than the Succulent Zone and is also colder. It is characterized by the *tola* bush, grasses, and, at least in the north, by small succulents.

Let us examine these two zones in greater detail. In the Succulent Zone the candelabrum cactus (*Cereus candelaris*) is typical of the lower slopes, while higher up are several kinds of pillar cactus which reach their greatest stature at about 3,000 meters, where in the south they are in places so close together as to form almost impenetrable forest. The cacti carry an epiphyte, *Tillandsia virescens*, and are associated with many smaller succulents. Throughout the zone there are many shrubs, all betraying their xerophytic character by their small leathery leaves or otherwise. In the north there are wide sandy stretches without large cacti, the shrubs being mixed with a small creeping Opuntia whose branches are made up of egg-shaped segments that easily break away and leave their spines in the skin of intruding travelers. The stream beds, both permanent and intermittent, in this zone have their own more luxuriant vegetation, including a thorny acacia tree.

The only feature of the natural vegetation here which is of direct importance to man is the edible fruits of the Cereus species. They are large juicy berries known as *guillaves* and *copaos*. Nevertheless the densest population of the Pacific slope lives in the clearings of this zone. The agricultural activities and crops are similar to those described in the desert oasis below, and the situation of the settlements has been determined, as mentioned elsewhere, by water and soil conditions.

Tola is a name applied not to any one species, but to various bushy plants which have a certain habit. Such shrubs constitute the major portion of the vegetation in the Tola Zone. The characteristics of the tola bushes are their dark evergreen color, squarrous habit of growth, resinous wood, and strong characteristic odor (see Fig. 25). Their maximum height is about one meter

FIG. 25—Yareta (center), tola (foreground) and ichu grass (background), a typical plant association of the Puna and Puna Brava zones. The first two are used for fuel; the last named is the leading fodder plant of the Central Andes.

FIG. 26—A stack of yareta ready for burning. This resinous plant forms one of the main sources of fuel in the Central Andes. The structure of the plant is revealed in the broken surfaces—closely packed radial twigs terminating in the smooth upper surface.

and a half. In the north the commonest species is *Lepidophyllum quadrangulare*, and in the south *Baccharis tola*. Associated with these are a number of other shrubs all belonging to the Compositae, and all with similar habit and xerophytic characteristics, as well as several grasses, including the handsome yellow-green pampas grass, and, in the north, a pillow cactus (*Opuntia*). The tola formation is monotonous to the eye, and the only change in its appearance summer and winter is due to the masses of golden flowers of the tola and the scarlet blossom of the Opuntia in the dry season. The grasses on the other hand flower in the wet season. There are of course variations in special situations—in shady spots ferns, in stream beds larger shrubs, and in damp places a closed turf of low plants. Furthermore, in the high valleys between the peaks of the Cordillera there are well-defined grassy swards, which begin in the tola belt and extend beyond it (ca. 3,500 m.—4,500 m.). This carpet consists of low grasses with other plants such as gentian and astrogallus interspersed.

The tola scrub is of great importance as fuel (see Fig. 35). It contains so much resin in wood and leaf that it will burn even while wet. Although the population is less dense in this zone than in the succulent belt below, there are numerous villages mainly engaged in agriculture. Some of the crops of the lower zone, such as beans and barley, are still cultivated here; the upper limit of wheat, however, is at about 3,700 meters. But in general the products of the Tola Zone are more similar to those of the Puna above it—potato, oca, and quinoa. The grass pastures of the high valleys are far-famed and lead to the keeping of large flocks by the inhabitants of the zone.

Vegetation of the Puna

In Figure 24 almost the entire area between the crest of the Cordillera Occidental and the brink of the slope overlooking the Amazonian plains is shown simply as "Puna." This does not mean that the natural vegetation is uniform throughout, but simply that the data are insufficient for the plotting of subdivisions. But in a general way it is possible to indicate dif-

ferences which, though affecting but little the general drab appearance of the Puna, are yet of importance as indexes to the utility of the land.

In the first place the climatic distinction recognized locally between Puna and Puna Brava is reflected in the plant cover. The altitude of the dividing line is not uniform, being sometimes below and sometimes well above 4,000 meters. In the upper, or Brava, zone the typical plants are the *yareta*, or *llareta*, bush and the *ichu* grass (see Figs. 25 and 27) with an occasional group of *quenua* trees. In the lower zone the ichu again is characteristic, but with it are the tola and several small succulents. In each of the zones there are other formations occupying special situations. It is commonly assumed that ichu grass is everywhere *Stipa ichu* (*Jarava*) and that yareta is *Laretia compacta*. It is as well, however, not to accept this, but to apply the names to two types of plant each of very definite habit and each of great economic importance—the first as fodder, the second as fuel (see Fig. 26). Ichu everywhere grows in hummocks or bunchy cones about half a meter high. The coarser upper blades form the chief food of the llama while the more delicate parts in the tuft are eaten by sheep. Yareta bushes seen from a distance resemble boulders; a closer view recalls hummocks of close-packed moss; but the uprooted plant reveals its true structure—a resinous woody stem with innumerable twigs branching as from the center of a globe and carrying leaves, buds, and flowers near their end. The habit of yareta is typical of a large number of plants in the Puna. They are adapted to resist the rigors of the climate. For the most part cushion-shaped or formed in rosettes, they crouch on the ground, their outer armor of close-packed leaves acting as a protection against wind. Buds are sheltered from hail by being embedded in the "armor;" likewise the small flowers, of which many open only in sunshine. After snow or rain the plant is like a sponge, retaining the moisture in face of the strong daily evaporation and absorbing it by the leaves.[3] Even the large shrubs which occupy stream margins, etc., are gnarled and twisted as is the

[3] August Weberbauer, *op. cit.*, p. 201.

FIG. 27—Ichu grass (*Stipa ichu*) in the Puna Brava zone. The sheltered and slightly moister hollow has been selected as the site for a corral for llamas and a shepherd's hut.

tree of the Puna, the quenua. Moreover the small leaves of the latter are leathery above and silky underneath—a sure sign that it keeps as much as it can of the available moisture. The quenua, which occurs singly or in groups, provides the only native timber and consequently is mainly found far from the haunts of man. Various reports seem to indicate that considerable woods of this species are still to be found in the neighborhood of Sajama.

The natural vegetation of the Puna changes little summer and winter. From January to March with the rains the cover becomes more close, and the grasses lose their brown burnt appearance to some extent. But there is no such contrast as appears in the lomas of the coast. Tola scrub seems to flourish chiefly in the valleys of the plateau and along the eastern piedmont. In the high plateaus of the southeast it would seem to be entirely replaced by ichu and yareta and similar bushes. Otherwise when an ecological survey of the Altiplano has been made the distribution of the various types will probably be found to depend largely upon soil, the many saline areas having a special vegetation—perhaps including yareta, the very sandy places another, and the swampy non-saline zones a third. The lower and damper parts are known to have a richer blend of grasses, forming good cattle pasture.

North of a line drawn from about Viacha round the southern and western sides of Titicaca there is quite a striking change, due presumably to less rigorous temperature extremes and increased rainfall. This area has been described as grass steppe composed of a variety of grasses growing both in hummocks and as an even carpet mixed with trefoil, geranium, gentian, verbena, etc., and dotted with a variety of shrubs and an occasional *culli*—a small tree (*Buddleia coriacea*) resembling the wild olive in appearance. The reed beds of Titicaca and Poopó require special mention. Many square miles in the bays and around the outlets are covered with these. The reed—called *totora* by the Indians—is mainly *Scirpus riparius*. It not only serves as cover for the innumerable water birds, but it furnishes the Indians with most of the material for their rafts (*balsas*) and sails, as well as being useful for many household purposes.

The chief fuel and fodder plants of the Puna have been mentioned. It remains to allude to the cultivated species. Amongst the native plants are the several potatoes, the oca (*Oxalis tuberosa*), and the grain-giving quinoa (*Chenopodium quinoa*). All these are cultivated with success right up to the snow line, and they form the main food staples of the Indian population. The quinoa when in bloom decks the country round Lake Titicaca and elsewhere with the tricolor of Bolivia—the green foliage capped by the red and yellow flowers. The introduced plants include barley and the haba bean (*Vicia faba*), both of which are grown widely in the Puna but not in the Puna Brava.

The only relief to the treeless aspect of the Puna is in the plantations about the haciendas—mostly of eucalyptus, a quick-growing tree that can stand light frost. But these are few and far between. The Bolivian government, however, anxious to foster tree planting, passed a law in 1918 providing for an annual bonus to be paid to every owner on the plateau of one thousand trees at least two meters in height, the amount of the bonus being 1,000 bolivianos except in the case of land on the shores of Titicaca where it was to be 500 bolivianos. This difference is an indication of the greater effort required to raise trees on the plateau itself as compared with the lake shores.

Vegetation of the Eastern Cordillera

The highest summits in both cordilleras rise above the typical Puna vegetation. On these the vicinity of the snow fields and glaciers is sparsely clothed by patches of dwarf plants growing in close mats. The species which compose them have been derived from the Antarctic regions; and these isolated areas of high mountain vegetation are the most northerly outliers of the south polar flora, whose domain must have contracted gradually and considerably since the last glaciation.

The higher temperatures which prevail in the deep valleys of the La Paz and Luribay Rivers accounts for a somewhat different vegetation from that of the plateau to the west. This area has been shown on the map as similar in character to the lower slopes

FIG. 28—Cactus vegetation at Obrajes in the La Paz valley. Its luxuriance and character bear witness to the relative warmth and dryness of this valley as compared with the Altiplano, 600 meters above it.

of the Western Cordillera because of the prevalence of succulent plants in both (see Fig. 28). But the vegetation resembles also in some respects the grass steppe of the higher eastern slopes of the Cordillera Real. The latter type has been shown in the upper valley of the Río Caine below Cochabamba; but this valley is now almost entirely under cultivation. It is probable that other deep valleys in the southeastern part of the sheet area should be classed separately from the Puna, for their aspect in places is that of an open woodland of feathery algaroba trees (*Prosopis*) with willows on the stream banks and wide stretches of rich green grass.

On the eastern slopes of the Cordillera Real and its foothills there are three distinct vegetation types: the grass steppe or meadows at the top, the dense "eyebrow" of the forest (*Ceja de la Montaña*) which cloaks most of the steep ridges and valleys, and the *Montaña* forest of the lowest slopes and flat valley bottoms. The existence of these three zones is well established, but it is as yet impossible to place with precision their upper and lower limits in this area. The high meadows and the *Ceja de la Montaña* are both in the belt of clouds,[4] and the line separating them is almost certainly determined by temperature conditions. It is the cold tree line, and it seems to vary according to configuration between 3,500 and 3,000 meters. The division of Ceja and Montaña proper is less noticeable, the two types merging into one another at about 1,200 meters altitude.

The form of the Cordillera is such that the flat-topped spurs and remnants of plateaus, described above as the relics of an old surface of erosion, fall mostly above the tree line; and it is upon these that the meadows are best developed. And we have seen, further, that this is probably the area of the most mature soils—a fact which may conceivably have something to do with the position of the tree limit. Grass forms the typical cover, knee-deep and thick, but there are also many shrubs which are derived from the forest below. Shrubs which, when first identified in the descent, are dwarfed and squarrous with small leaves, are found lower down to become larger while their leaves increase in size,

[4] Cf. pp. 86 and 87.

and finally after forming isolated clumps of trees they may be recognized as full-grown members of the Ceja forest. According to topography the transition from meadow to forest may be gradual or abrupt. North of Cochabamba there are parts of the cordillera where sheer rock faces of great height separate the high meadows from dense luxuriant forest.

The "eyebrow" of the forest is presumably so named from the density of its undergrowth and for its position above the main forest (see Figs. 29 and 37). Throughout its whole breadth the zone is penetrable with difficulty, save along stream courses and where paths are kept clear by constant use. This density is the direct result of the daily moisture bath which the mountain slopes receive in the form of mist. The effect of rainfall is thus greatly enhanced, for not only is the soil kept constantly moist by the reduced evaporation, but many of the plants are able to extract moisture from the air. The daily mists which act as a screen to the sun's rays also lower considerably the air temperature in the forest. The character of this jungle varies somewhat with the situation. Where it is exposed to wind, or where soil is thin, the tree forest is reduced to bush and on the sharp spurs to scrub. It is nowhere a forest of giants like those of the flat valleys and plains below; but for the most part it is composed of trees of great variety, from broad-leafed species to tree ferns. The upper branches spread to form flattened crowns and are often bound together by an intricate network of lianes, so that paths cut in the forest have the aspect of tunnels, which are frequently floored with slippery mud. Many of the trees have bright flowers, but these are seen by man chiefly in places where the trees give place to the lower bush. Orchids, tillandsia, and other epiphytes as well as mosses are crowded on the branches, and near the ground is a dense tangle of roots, rotting trunks and branches, and huge soft cushions of mosses—especially sphagnum—and lichen. The increasing temperature is marked by changes in the composition of the forest towards the lower levels, the most obvious of which is the presence of palms and high cecropias below an altitude of about 2,700 meters.

FIG. 29—Illimani from the Yungas. The steep eastern face of the mountain with its permanent snow overlooks deeply dissected valleys clothed in the dense "eyebrow of the forest" (*Ceja de la Montaña*). Cloud hangs almost constantly on these moist upper slopes.

One of the groups of plants most typical of the Ceja forest is that of the cinchonas whose bark is the source of quinine. Of these there are some thirty species and they are found throughout nearly the whole altitudinal range of the forest, but best developed about the middle of the zone. Like other plants of the Ceja the cinchonas form large trees in the situation best suited to their requirements, and decrease in size and luxuriance upwards and downwards to their limits which are about 3,000 and 750 meters respectively. The lower part of the Ceja forest is also the home of the coca shrub (*Erythroxylon coca*), and this native plant, from whose leaf cocaine is derived, has been isolated and cultivated for many centuries by the natives. Large areas of the forested slopes have been cleared and terraced to form coca fields, but since the Spanish Conquest the ground is shared by coffee, maize, and subtropical fruits.

The Montaña forest lies below the cloud belt and derives its moisture entirely from rain or ground water. The lower valleys are largely filled with detrital material; and soil and water as well as temperature conditions combine to support much higher trees than on the mountain slopes. The great valley forests of the foothills, then, belong to the type known as tropical rain forest. Its leading features are the high tree trunks often buttressed at the base, the dense panoply formed by the crowns, and as a consequence of this the darkness below and the resulting thinness of undergrowth. This is the outstanding vegetation of the foothills and plains beyond. But there are areas, which still remain to be accurately located and explained, where a much more xerophilous vegetation is found. This includes both the savanas and grass steppes which are the main cattle-raising sections of southern Peru and northern Bolivia. But they lie beyond the limits of the La Paz sheet.

Recent observations of Rusby on the flora of certain relatively dry valleys of the Eastern Cordillera (cf. foot of page 94) disclose a xerophytic vegetation including cacti and various shrubs. Even near Cañamina (1550 m.) there are cacti—up to 55 feet high—and the forest is largely composed of Mimosaceous trees. Thus, topography greatly complicates the altitudinal zoning of vegetation described above.

CHAPTER VIII

ANIMAL LIFE

If it were possible to take a census of individuals of the animal kingdom apart from man in the area of the La Paz sheet and compare the total with that of a world average for similar areas, the La Paz total would probably be far above the average. This is because life is peculiarly abundant in two parts of the area—along the coast both in the water and near it and in the forests of the northeast. The reasons for the abundance of marine forms in the cool coastal waters and consequently of those which prey upon them, have been stated in Chapter IV; and it is because the forests are upon the slopes of the Andes that animals are so numerous there, the varied altitudinal assortment of climatic and vegetation conditions leading not only to a great multiplicity of species but also to remarkable fecundity in reproduction. The truth of this statement is perhaps not very obvious to the casual observer, for the chief evidence of the teeming life of the sea is the great flocks of birds about its margin; and again, in the recesses of the forest, while birds and insects are relatively visible, the mammals are but rarely seen by man. In the great intervening region of puna, mountain, and desert, on the other hand, concealment is more difficult, and such is the monotony of the landscape that every living creature picked out makes a distinct impression upon the traveler.

The same causes which have determined the main division of the vegetation at the eastern crest of the Andes account for an equally important frontier between the two great faunal regions. It is due to its high Andean fringe that the continent of South America—the so-called Neo-Tropical Region of zoölogists—is not subdivided by a parallel of latitude but by a diagonal line which leaves the Pacific near the equator and reaches the Atlantic in latitude 30° S. All but the forested sec-

tion of our area lies to the southwest of this faunal division and in the "Patagonian" or "Chilean" subregion. Just as the features of climate and flora of the far south are carried northward along the western fringe of the continent nearly to the equator by the height of the Andes and the presence of a cold ocean current, so also with the fauna. In the Puna and coastal belts secular distribution has operated in the most recent geological periods from south to north; in the forest belt it has worked at least in part from north to south. In the Puna, climate and vegetation similar to those of the Patagonian pampas have led northward to our region and beyond it the American camels, rodents, and many birds and lower forms of life. Waters of like temperature to those of the Antarctic have induced the crustaceans, fishes, whales, seals, as well as penguins and other birds characteristic of high latitudes, to extend their range along the entire coasts of Chile and Peru; while, on the other hand, birds and probably other animals also originally located in the extreme north of South America have slowly spread southward along the slopes of the Andes, the various species often following a narrow strip of definite altitude in which alone they find their particular requirements of environment. An interesting exception to the northward spread of the animals inhabiting the higher parts of the Central Andes is the small spectacled bear—the only bear of South America—which is evidently an intruder from the northern continent, but now he barely reaches to within 3,000 miles of his nearest relative of the bear tribe in northern Mexico. The reality of the faunal barrier of the Eastern Cordillera may be illustrated by the range of the flamingo, which breeds in the Puna, and by that of the condor and other birds of prey which haunt the mountains and avoid the forest. These birds habitually descend to the Pacific coast in search of food but do not seek low altitudes east of the Andes. The La Paz sheet then, provides a cross section of several life corridors by which plants and animals ever since the uplift of the mountains have spread north and south and only in the most minor degree east and west. Furthermore, these parallel zones are corridors not

merely in relation to the secular spread of life but also in regard to the seasonal rhythm which influences many creatures. Thus the birds of strong flight, such as the golden plover, which nest in Labrador and thereafter make for equivalent latitudes in the southern hemisphere use the Puna, with its cool air and its lake feeding grounds, as an avenue on their return flight. This fact is especially striking in that the southward migration is made by the way of the Atlantic seaboard.

An attempt to explain the abundant representation of some orders of animals and the paucity of others in the region would lead us into the geological history of South America—a field upon which we cannot enter here. But it is our purpose to indicate the more important effects of local environment in determining these features as well as in accounting for certain peculiarities of form or of habit. So far as the writer knows, there has been no systematic zoölogical study of this area as a whole. Orbigny, Castelnau, Créqui-Montfort, and other explorers have made notes and collections along certain limited routes, while several collections have been made by the American Museum of Natural History in different parts of this and neighboring districts. The data are insufficient to determine the distribution of all but a few species, and nothing has been written regarding the animal ecology in the area. It will be evident that the region and especially the eastern forests offer a wonderful field for future study of the animal associations and of their interdependence. We must, therefore, be satisfied with the scattered observations of explorers and utilize notes regarding life habits derived from analogous localities.

Life on the Coast

Very complete faunal studies have been made by R. E. Coker, H. O. Forbes, and R. C. Murphy of the Peruvian coast down to the western limit of the sheet, special interest having been aroused here by the high economic importance of the guano-producing birds.[1] Little guano in commercial quantities remains

[1] Robert Cushman Murphy, (104). The papers by Coker, Forbes, and others are referred to in this.

on the shores of our area because there are no islands where the birds can remain undisturbed, but the general life conditions are very similar, and observations made farther north may be taken as applicable here.

The cool, up-welling water of the coast carries unicellular algae and other humble plants in vast quantities. Upon these feed innumerable microscopic animals which in turn provide sustenance for the crustacea, the fishes, and the whales. Seals, sea lions, and sea birds in enormous numbers spend gluttonous lives in consuming the fish which they need never go far to seek. The birds, mostly gregarious, nest on the sea cliffs and—preferably—on islands where such exist and when left undisturbed will rapidly accumulate guano about their nests. The guano—preserved by the dryness of the climate—attracts man; the eggs and the birds themselves attract a host of birds of prey. Quantities of sea birds are killed in this way, and even the noble condor of the cordillera has been revealed as a systematic egg sucker. Such is the chain of life on the coastal fringe of the region.

So far 163 species of marine fish have been recorded from these coastal waters,[2] and there are doubtless many more which have not yet been described. The ecological grouping of fishes shows aggregations adapted to all types of habitat that exist along the coast. They include types which live in rocky pools, others which are adapted to the deeper rocky floor, and the flat fishes which love the shallow, sandy stretches. Then there are the fish which occur in immense schools and feed upon the plankton; the herrings, or *sardinas*, of which there are three species, and the anchovies predominate amongst these. These schools are attacked by larger predaceous fishes such as the mackerel and bonito. On the shore itself and in shallow bays there are quantities of large crabs and lobsters as well as scallops, oysters, whelks, and snails. The great bulk of the coastal fishes, although far north of the tropic, belong to temperate or sub-tropical types akin to those either of the California region or of the Mediterranean.

[2] Robert Cushman Murphy, *op. cit.*, Vol. 9, p. 58; also John Treadwell Nichols and Robert Cushman Murphy, (105).

But the warmer water to seaward of the Humboldt Current harbors tropical species such as sharks, rays, and flying fish; and some of these make inroads on the cooler waters in search of food. The schooling fishes and especially the *anchovetas* form the main food of the gregarious guano-producing birds as well as of the sea lions (*lobos*) and seals.

To give some idea of the abundance of life we may quote two passages. In the first, Murphy, describing the schools of anchovetas, says: "During the afternoon of February 2nd, 1920, . . . I estimated that a hundred schools of anchovetas were within sight. At times when the bonitos attacked them from beneath, large areas of the surface would be so broken by the leaping of the little fishes that the ocean hissed as though a deluge of rain were descending upon it. The most remarkable sight of all was the manner in which whole herds of lobos were lolling and frolicing among the anchovetas, gorging themselves to the limit of their capacity. . . . Their [the fishes'] appearance from above is amazing, for the quivering, silvery creatures seem to be packed together like sardines in a tin except that their heads all point in one direction."[3]

Again, Frank M. Chapman, referring to the bird life, describes a scene on the northern Peruvian coast in November, 1918:

"Seaward, like aerial serpents, sinuous lines crawled through the air in repeated curves which lost themselves in the distance, or processions streaked the sky or water in rapidly-passing, endless files, flowing steadily by, hour after hour, during the entire day without ceasing, and with but slight breaks in the line. . . . The cormorants fished from the surface where they were evidently surrounded by a sea of the small fry, which, with much plunging and diving, they gobbled voraciously, until, their storage capacity reached, they rested in great black rafts on the water, waiting for the processes of digestion to give both excuse and space for further gorging. The boobies [gannets] fished from the air, plunging headlong and with great force from an average height of fifty feet into the water almost directly. It was a cur-

[3] Robert Cushman Murphy, *op. cit.*, Vol. 9, p. 65.

tain of darts, a barrage of birds. The water below became a mass of foam from which, if one watched closely, hundreds of dark forms took wing at a low angle to return to the animated throng above, and dive again; or, their hunger satisfied, they filed away with thousands of others, to some distant resting place. . . . But the most amazing phenomenon in all this amazing scene was the action of flocks of boobies of five hundred to a thousand birds, which, in more or less compact formation, were hurrying to join one of the booby squalls which darkened the air over the fishing grounds. If, unexpectedly, they chanced to fly over a school of fish, instantly, and as one individual, every booby in the flock plunged downward and in a twinkling the air which had been filled with rapidly flying birds was left without a feather."[4]

The fishing birds which exist in our region in the greatest numbers are the *guanay*, or guano bird, a white-breasted cormorant; the *alcatraz*, a pelican; and the *piquero* ("lancer"), which is a gannet or booby. But there are many others which like these nest on the islands and feed in the water; for instance the skuas, the kelp gulls, penguins, and a diving petrel all represent emigrants from far southern latitudes. Moreover, there are numerous small waders which derive their food from the shore line, as do some of the lizards, and an otter, normally a fresh-water animal, has been tempted to a maritime life by the prodigality of the fish supply.

The fauna of the desert pampas of the coast lands I believe has not been described. It seems clear, however, that it is restricted mainly to the neighborhood of the valleys. Insects are numerous, as are the lizards which prey upon them. Snails are very numerous near the coast. A wild dog is frequently mentioned, while an otter haunts the more permanent streams. Of the birds we have little information; but burrowing owls and the "desert bird" (*Geositta*) are characteristic, and vultures are constantly on the lookout for game or carrion. On the upper fringe of the desert brilliant humming birds hovering over the

[4] Frank Michler Chapman, *Bird-Lore*, Vol. 21, 1919, pp. 89–90.

scarlet cactus flowers form a distinct color note in the landscape. Colibris and thrush-like birds are reported as common on the Pacific slope, and they play an important part in the fertilization of plants and in the distribution of the seeds of those whose fruit they eat.

Life of the Western Cordillera and Puna

As has been indicated the high Andes have a fauna all their own; mammals, birds, fishes, and other vertebrates, and probably lower animals as well are quite distinct. We have but to remember the clear atmosphere and the absence of close vegetation to realize that the weaker animals, in order to continue to exist, must be provided with some defense against their far-seeing enemies. This defense is either great speed, as in the vicuña and chinchilla, or in protective coloring, as in the majority of the Puna birds; while the habit of some animals, such as the viscacha, of spending the day in a burrow and feeding by night is doubtless in part protective. The cold climate is met in the case of the mammals by the provision of peculiarly thick wool or fur. Birds of prey are numerous, beasts of prey less so; and save for the waterfowl and swamp birds the great majority of the fauna is vegetable-eating—even many of the lizards. All of these animals have become completely adjusted to life at high altitudes, and most of them do not descend far below the typical Puna region. This may be due in part to the change in food conditions lower down, but in the main the temperature and pressure are the determinants of their range. Thus the domesticated llama, when driven down to the coast or into the Yungas, actually suffers and can only be kept at low altitudes for a short time.

By far the most striking mammals of the Puna are the huanaco and the vicuña. These are the American representatives of the Camelidae, which they resemble somewhat in aspect. More common than these and therefore much more often referred to are the llama and alpaca. Zoölogists, however, do not admit that they belong to the natural fauna, believing either that the

llama is derived from the huanaco and the paca or alpaca from the vicuña or that each is derived from the crossing of the two native animals. It is clear that there is much variation in individual llamas and alpacas, and it is further evident that domestication of both by the Aymará Indians is of very ancient date, so that there seems no reason to doubt that this is so. The altitudinal limits of the two wild species in this region are usually given as about 2,500 meters and 5,000 meters, or practically up to the snow line. The huanaco is here at about its northern limit and is no longer common. The region is near the southern limit of the vicuña, on the other hand, but this animal is still common in the area. Both species are gregarious; but the huanaco, where common to the south of our area, moves in large herds—up to 500—while the vicuña groups are small—20 to 30. The young are born in February, when the temperature and rainfall are high and the pasture at its best. The vicuña is smaller and of lighter build than the huanaco. All this llama tribe resemble each other in aspect, having a look of the sheep as well as of the camel. The wild species are brown in color, but the llama and alpaca may be brown, white, gray, mottled, or even black. The coats of the vicuña and alpaca are of long, thick, silky wool which is of great value.

The rodents are represented by a number of mice; but the best known are the larger chinchilla, viscacha, and cavy. The chinchilla, of which the "blue" variety inhabits our area, is a squirrel-like animal which lives in burrows or crevices in the rocky parts of the Altiplano and in the two cordilleras up to about 5,000 meters. The fur is close, silky, and valuable, so that the animal, hunted systematically by the Indians, is fast becoming extinct. The viscacha, which is larger and of heavier build than the chinchilla, has a less valuable fur, but it is also much sought after. It is susceptible of domestication, and some attempts are being made to cross it with the chinchilla. The hunting of both species is carried on by the use of ferrets to drive them from their burrows. No fate of extermination awaits the third of the rodents—the Bolivian cavy, its extreme fecun-

dity being sufficient defense against this. It lives in the more deserted parts of the Altiplano and mountains where there is enough soil to support its warrens. The smaller domesticated variety of the cavy is the well known "guinea pig" which is kept —or rather exists—in numbers in and about every Indian dwelling and serves as a food for the natives. Other mammals of the Puna include the spectacled bear; the puma, and the wild dog; all of which are found in small numbers up to the snow line.

The natural fauna of the Puna is much less obvious to the traveler than is the domestic, of which more will be said in another place. But the bird life is plentiful. As has been indicated, similar environment has led to the development of an avifauna derived from lower altitudes in the southern part of the continent; and the requirements of southern birds of plain, marsh, and lake are fully met on the Puna. Thus we find southern geese, ducks, grebes and coots, divers, cormorants and gulls in enormous quantities on lakes Poopó and Titicaca as well as on the numerous mountain tarns; while great numbers of plover, snipe, avocets, curlews, ibises, and herons inhabit the plateau and especially the swamps. Amongst the small birds the pipits are especially plentiful. The waterfowl are of varied hue and habit. They have admirable feeding grounds and nesting places amid the wide reed beds around the margins of the lakes, and they are practically unmolested, for the natives do not trouble to hunt or trap them to any extent. Only the grebes appear to suffer much at their hands. These they hunt by night, dazzling them with torches and so taking them from the water alive. The most brilliantly colored bird of the Puna is probably the Andean flamingo (*Phoenicopterus chilensis*), a bird whose breeding grounds have never been discovered. Some of these localities, however, are said to be known to the Indians, who are reported to find their eggs a delicacy and are probably thus causing great inroads upon this beautiful species. The muddy margins of small lakes almost certainly form the nesting grounds of this bird. Such places are numerous all along the Cordillera Occidental; and it may be noted that in the La Paz

sheet the name Parinacota, which is the Indian word for flamingo, occurs twice—designating a village 40 kilometers west of Sajama near to several lakes, and a lake lying to the southwest of Isluga and on the 69th meridian. It is difficult to understand why the flamingo, in such an environment and virtually defenseless, should be endowed by nature with such a gaudy coat. The majority of the plovers, snipes, and pipits, i. e. the birds of the plateaus other than waterfowl, are dun-colored and blend admirably with the background of ichu grass and earth. The snipe family provides an interesting example of the effect upon form of a puna or tundra environment. Separate genera are found which have entirely lost the characteristic long bill, necessary for probing the wet mud in search of worms and grubs; and, while one of these has developed the general appearance of the ptarmigan, another has taken on the aspect of a large lark.

The condor with his huge wing stretch, the smaller turkey vulture, as well as other birds of prey and carrion feeders are a prominent feature of the mountain landscape. The powerful vision of these birds is remarkable, and the death of any animal is quickly followed by their arrival on the scene. The condor's eggs are laid at the end of February and are not hatched for some six weeks. It will, therefore, be noted that, as in the case of the vicuña, the young begin life in the late summer.

The fishes of the plateau have been studied notably by Agassiz[5] and more recently and completely by Neveu-Lemaire,[6] Eigenmann,[7] and Evermann and Radcliffe.[8] They are interesting chiefly from the fact that they have evidently reached their present isolated habitat when the waters of the Altiplano were still tributary to the Amazon basin. The fish comprise but two genera. Of one of these there are two species, but of the other (*Orestias*) there are nine species or varieties; and Neveu-Lemaire states that this relatively large number of species in one genus may perhaps be explained by adaptation to life at high altitudes

[5] Alexander Agassiz and S. W. Garman, (92), also Alexander Agassiz, (93).
[6] M. Neveu-Lemaire, (95).
[7] Carl H. Eigenmann, (108).
[8] Barton Warren Evermann and Lewis Radcliffe, (109).

so recent that the forms are still in course of evolution and differentiation. The same author describes a number of mollusks as well as two frogs, one of which was observed by Agassiz to make a practice of sitting amongst the water plants at the bottom of the lake for hours on end.

Life on the Atlantic Slope

The difficulty of access to the forested slopes of the eastern Andes accounts for the paucity of accurate information regarding the fauna of this section. But three facts stand out clearly: it is extremely rich both in kind and quantity; it is entirely different from that of the Puna; and, like the vegetation, it occurs in zones. The mammals seem to be more abundant on the lower slopes and valleys than higher up; but this characteristic is probably much less marked in the birds and insects. These are often quite restricted in altitudinal range, and when the subject has been closely studied we shall undoubtedly find a close relationship between the temperature zones on the one hand and the ranges of special plants and of the animals dependent upon them on the other. The birds, while they include many which have brilliant plumage—as in other forested parts of South America, are probably in the main inconspicuous. The brightly colored birds, however, are better known because more easily observed and collected. The majority have short wing feathers, indicating that they are not strong fliers. These birds in fact spend their lives in a small locality, and their flights are little more than jumps from tree to tree.

The greater part of the forests falling within our area is of subtropical type—the dense, tangled, wet growth of great luxuriance, described in the previous chapter as the Ceja de la Montaña, which extends from eastern Bolivia northward to central Colombia, where its fauna has been studied by Chapman, whose work[9] on bird distribution of that country is a model. The life throughout the entire zone is believed to be exceptionally uniform, but at present the extent to which it varies with lati-

[9] Frank Michler Chapman, (106).

tude cannot be determined. Chapman states that its fauna has been derived in the main from the tropical zone below it—the specialization having begun presumably with the elevation of the Andes or perhaps re-started after the Ice Age. The species of the subtropical forest, then, mostly have their more ancestral relatives below them in the tropical forest; but some, as Chapman shows, have come from the north following their particular altitudinal zone for thousands of miles, advancing slowly but surely —perhaps no more rapidly than ground-haunting mammals; for, as we have seen, individual birds of this type do not move far from their birthplace. From Chapman's description of the bird types we may note that "tanagers are the most numerous in species as well as in individuals, . . . thrushes, while far less numerous in species, have almost as large a proportionate representation. Guans, trogons, capitos, toucans, dendrocolaptids, cotingas, and wrens are all characteristic of the sub-tropical zone and, in the Colombian Andes, have about half as many species in it as in the Tropical Zone. The flycatchers are about one-half as numerous in the subtropics as in the tropics. . . . As might be expected, few true finches inhabit the subtropical zone, but the tanager-finches . . . are almost restricted to it."[10] It may be added that the wood hewers are very numerous also.

It would be useless with the uneven data in hand from chance references to attempt to compile a list of important birds of the forest in the La Paz area. But with the mammals the matter is otherwise. For there are a few types of these which undoubtedly predominate. The high grass steppes and the upper fringe of the forest are the grazing grounds of the deer, of which there are two kinds—the guemal, which is akin to the North American types, and the dwarf padua, which hails from the south. The padua resembles a large terrier dog in size and bears the smallest of antlers. In this zone also there are armadillos, although these are more typical of the dry valleys in the neighborhood of Cochabamba. The Carnivores are represented in

[10] Frank Michler Chapman, *op. cit.*, pp. 138–139.

the higher zone by the nasua or coatimundi which lives on small animals, and various opossums are found in the upper tree zone, some of which have a bare prehensile tail indicating their arboreal life. The spectacled bear, already mentioned, also comes down the eastern slope to the edge of the forest.

The collector of mammals in the forest must rely upon the trap, for he cannot penetrate far from the trails, so thick is the undergrowth in all but the high rain forest of the flat land; and if he could do so, he would not see any of the large group of animals which move only by night. It is impossible at present to determine ranges of even the leading species of the forest beyond stating that the sloths and most of the monkeys are found only below one thousand meters. Above that line probably the most numerous are the peccaries (South American swine) and agoutis, both of which live on roots, bark, fruits, etc. The jaguar, the largest of the cat tribe in America, and the ocelot, his smaller cousin, are the chief beasts of prey. Along the rivers there are capybaras, or so-called "water pigs"—large swimming rodents, and coypus. Other rats of various size and color have a spiny fur which is a defense against snakes; and these latter doubtless are numerous. All authorities agree that the least attractive of all animals of the Andean fringe is the tayra, which is virtually a huge weasel. It is some three feet long, almost black in color, and is gregarious. It is always described as hideously ugly and extremely vicious.

We may conclude this brief account of the animal life in the La Paz sheet area by emphasizing the climatic control of life in respect to reproduction. We have seen that on the high plateaus and mountains the young of the condor and the wild ruminants are born in the hottest month and towards the end of the rainy season, and this rule probably holds good for many other animals. The food supply is then at its maximum, and sufficient time remains before the cold weather to enable the young to acquire resistance to it. On the coast and lower slopes on both flanks of the Andes climate exercises no such definite control. Temperatures are much more equable, and the food

supply of most animals is constant. Thus the sea birds breed all through the year but with a maximum intensity in the summer (November to January), while the passerine (perching) birds of the coast lands breed entirely in that season. In the forests there is no well-marked seasonal rhythm either in plant or animal life, although we may suppose that there is some variation in the amount of reproduction corresponding to the wetter and drier periods.

CHAPTER IX

THE INHABITANTS AND THEIR ADAPTATION TO THE ENVIRONMENT

The Races and Their Origin

Students of archeology, anthropology, and philology have devoted much research to the Central Andes. Their main task has been to determine the origin and affinities of peoples who have left their marks in various ways upon the region. In some respects they have been remarkably successful, although the veil of mystery which long shrouded the entire subject still hangs over some of its important phases. But recent researches of linguistic authorities[1] have thrown light upon one leading point —the affinities of the Urus, the most primitive race inhabiting the Altiplano. The conclusions of philologists regarding the early peopling of the Central Andes may perhaps be accepted provisionally, since they seem to be in harmony with the results obtained by workers in other fields.

The Central Andean regions were occupied in the first place by extremely ancient peoples who came from the Amazonian plains and whose type has been preserved for us by the Urus. This population, living entirely by hunting and fishing, were later submerged by a pastoral and farming people—the Collas or Aymarás, who possessed a much higher civilization and were the architects of the magnificent buildings of Tiahuanaco. Lastly, at a more recent epoch, the Quichuas appeared, a conquering people who gradually extended their rule over all Peru and the adjacent lands and whose language spread at the expense of Aymará, just as the latter had previously spread at the expense of Uru, although perhaps for different reasons.

The population in the area of the La Paz sheet comprises a

[1] G. de Créqui Montfort and P. Rivet, (123) and (124).

small remnant of the Urus in a few places on the plateau and larger but unimportant numbers of their Amazonian relatives in the lowland forests. But the great mass of the people are Aymarás and Quichuas, each associated—in degree varying with locality—with half-breeds whose blood is in part Spanish.

Until recent years nothing was known to science of the affinities of the Urus, and yet their importance is as a link with the past and consequently affects chiefly anthropology and history. The Urus live today in small groups near the outlet of Titicaca, along the Desaguadero, and north of lake Coipasa where they are known as Chipayas. They are mainly occupied with fishing and hunting aquatic birds. In 1901 Polo—from the study of Spanish treatises—was able to demonstrate[2] that a people speaking a language known as Puquina were found at the time of the conquest all over the Altiplano and on the Pacific coast throughout our area. The early Spaniards referred to Puquina as one of the *lenguas generales* of Peru, and a single precious text of this has been preserved.[3] But the affinities of the language long remained unknown. In 1894 Grassière established[4] a connection between Puquina and the Arawak tongues of Amazonia, and Créqui-Montfort and Rivet after careful analysis have now pronounced Uru to be the Puquina dialect with the modifications of three centuries masking it. These authors, like many before, point to the fact that the Urus, surrounded by races of shepherds and farmers, are themselves fishers and hunters and conclude that this is explained by their Amazonian origin. These river fishers and hunters of the forests spreading up to the Puna became the fishermen of the lakes and ultimately, pushing down the Pacific slope, adapted their habits so as to draw their sustenance from the ocean. The Urus, while either extinct or absorbed on the Pacific coast and in most of the plateau, have retained their individuality, habits, and language in the few localities mentioned.

[2] José Toribio Polo, (125).

[3] Written by a Jesuit, Alonso de Barzana, in the sixteenth century and preserved in the "Rituale seu Manuale Peruanum," Naples, 1607.

[4] R. de la Grassière: Langue Puquina, Leipzig, 1894.

The origins of the Aymarás and of their conquerors, the Quichuas, remain in obscurity. Some have believed that the two races are related; but the anthropologist Chervin, after detailed investigations and measurements stated[5] that they constitute two distinct brachycephalic peoples.

It seems likely that prior to the advance southward of the Quichua armies of the Incas the entire highland area of our region was dominated by the Collas, or—to give them their modern name—the Aymarás; but little is known regarding the history of the period before the conquest by the Inca of Collasuyo, the title by which most of our region was known in ancient times.

The most eloquent testimony to the greatness of the race which once ruled in the Collasuyo, is the ruins of their monuments. The most noted of these are found at Tiahuanaco, a few miles east of the southern end of lake Titicaca. Here are remains of buildings—probably temples or palaces—constructed out of massive blocks of stone and showing a very advanced development of the art of masonry. It is not known whether these ruins are vestiges of an isolated empire that existed in this part of the plateau or whether they were the work of the same people who built the megalithic structures at Cuzco, Ollantaytambo, and other places on the Andean highlands. It is thought that they were ruins even at the time the Inca empire was founded, since there existed among the Indians no tradition that would connect them with that dynasty. This place was apparently the site of an ancient city of great size, for the ground over an area of several square miles, and to a depth of a meter or more is filled with the relics of an ancient settlement. This was probably the metropolis of the entire region, since, although there are evidences of a large population over almost the entire lake region, there is no other known center such as this. The ruins, moreover, point to the existence of a well organized authority and apparently a far greater production than now is found or than even seems possible in this high, cold region. This has led some to conclude that there must have taken place an extreme

[5] Arthur Chervin, (126).

change of climate or even to conjecture that the entire plateau has been subject to a great elevation in very recent times. But it is also possible that some economic system was devised whereby the people who lived in this populous center might be supported by the more productive lands of the valleys that descend from the surrounding plateau. It is known that the Inca dynasty in later times employed a system of tribute whereby the products of many other regions were poured into the storehouses of Cuzco and other royal depositories. A similar system had been evolved in Mexico, where the populous capital of the Aztecs, situated on their narrow island home, was supported by the contributions exacted from conquered tribes. Perhaps some such scheme of support enabled the people of Tiahuanaco to live in what seems to the modern observer an impossible location for a large city.

It is known, too, that the Incas had developed a system of colonization, whereby the various diverse regions were settled and their products put at the disposal of the highlanders. They had also the system of the *mita*, or forced labor, by which the services of any man in the empire might be drafted periodically to work for the emperor and his associates. It is possible that these arrangements were not innovations introduced by the Incas but were customs which had been established among the aboriginal peoples from remote antiquity and which had served to make the existence of such a city as the ancient Tiahuanaco possible in its unfavorable site.

The Collas have a long legendary history. Their culture apparently far antedated that of the Inca empire. A list exists containing the names of 92 kings who are said to have reigned before the establishment of the Inca dynasty. Moreover, the excellent workmanship displayed in their ruins, the relative perfection of social organization among the Aymarás, the existence of many varieties of cultivated plants, and the evident antiquity of domestication of the llama and the *cuey* (the cavy, or guinea pig) all point to a very ancient culture that existed in this region of Collasuyo. Consequently it is not improper to

consider the highland section of the La Paz sheet as distinctly the Aymará country.

It is clear that Quichua penetration under the Incas operated from north to south, and the topography of the interior tableland of the Central Andes is such that between the mountains of Vilcanota and the southern limit of our area the only great natural obstacle to conquest is Lake Titicaca. It is behind this barrier that the main body of the Collas have maintained themselves, resisting all efforts to incorporate them into the unity of the great Inca empire. In spite of subsequent conquest by the Spaniards, they remained and remain little mixed with other ethnic elements, speaking their own language (somewhat corrupted by Quichua and Spanish, it is true) and preserving their own customs much as in ancient times. In the southern part of the sheet area, however, the population today is thoroughly Quichua in culture, a fact which may perhaps be accounted for by deliberate colonization on the part of the Incas of the southern marches of the empire.

The great bulk of the people, then, are either Aymarás or Quichuas. Mainly in the towns there is a fair proportion of whites, the descendants of the Spanish conquerors, while a larger body scattered throughout the land are the mestizos, or *cholos*, who carry white blood in widely varying proportions. The Bolivian census of 1900 gave the white population of the Republic as 231,000, or over 14 per cent of the whole. But the great majority of these are undoubtedly people of mixed blood. Racial statistics for the parts of Chile and Peru in the region are not available. In the coastal districts there is some admixture of negro blood, derived from slaves introduced by the Spaniards. The tale of races in the region is completed by the small Uru groups above-mentioned, and by the Moseteños, Chimanes, and Yuracarés (in order northwest to southwest), forest tribes of purely Amazonian affinities, but practically nothing is known of their distribution.

The two great peoples of the Central Andes closely resemble each other in several characteristics; thus they are brachy-

cephalic (index 82), and their average stature is about the same (about 160 centimeters, or 5 feet 3 inches); but the Aymará has a longer and broader thorax, and from this results a body abnormally long in proportion to the legs. The Aymará, then, has a more massive appearance. He is also somewhat lighter in skin tint. His forehead and his chin recede more, and the former is narrower than in the case of the Quichua; while he is wider across the cheek bones, so that his face has a typical lozenge shape. The Aymará, in spite of his shorter legs, takes a longer pace. He wears his hair loose, clipped at the shoulder, while the Quichua wears his in a plait. There are also minor differences in dress, while all observers notice a striking psychological divergence. The Quichua is distinctly docile, while the Aymará is intractable, independent, and often stubborn. The Quichuas have better-developed social qualities; the Aymarás, being lovers of solitude, commonly live in small groups or even single families. In discussing the color of the Aymarás, Forbes[6] notes distinct differences of tint in the various climatic provinces. In the dry regions, whether hot or cold, the color is described as blackish brown; in cold, moist areas, light coppery brown; and in the hot, wet, eastern valleys, yellowish brown.

Distribution of the Population

Plate I is a map showing the approximate distribution of population in the La Paz sheet area. It may be considered as sufficiently reliable to give a basis for discussion at least of the outstanding features of the distribution and agglomeration of people in the region. Unfortunately, no very recent statistics are given in sufficient detail to allow of the construction of a population map. We have, therefore, had recourse to the official census returns of Bolivia, Chile, and Peru made respectively in 1900, 1907, and 1876. The lack of contemporaneity in these three documents is of course a drawback, as is their antiquity. Furthermore, the census returns themselves cannot be regarded as accurate, since the difficulties of taking the census—widely

[6] David Forbes, (122).

scattered population and native hostility to enumeration, to mention only two of them—have so far baffled the governments concerned. This map should be compared with Plate II for the occupation and mode of life of the various groups.

The method of constructing the population map was as follows. The boundaries of the smallest political units for which population was given in the census were plotted on the map, and it may be noted in passing that for most of the region these boundaries have appeared on no map hitherto; indeed the position of such lines is often quite vague in the minds of the inhabitants themselves. In the light of geographical knowledge an estimate was then made regarding the real location of people within these small political divisions; and lines were drawn limiting the various groups. Little difficulty was encountered in fixing the limits of strictly sedentary population, as, for instance, in mining districts or areas under irrigation. But where the physical environment is relatively inhospitable and the inhabitants have to move over wide areas to gain their sustenance, an effort has been made to spread such people over the total land on which they are in any way dependent. Thus throughout by far the greater part of the map low densities are shown covering wide spaces with but little variation, instead of villages or hamlets as the centers of small areas of greater density. For two reasons the former method is regarded as the better. First, because there are many small aggregations which do not appear on the map; and, secondly, because the Indians of these areas are largely occupied with pastoral pursuits and their flocks roam far and wide over the plateaus.

The population represented on this map is approximately 828,000, made up as follows: in Bolivia 635,000; in Chile 62,000, and in Peru 131,000. These numbers accounted for the following proportions of the total populations of the three countries: Bolivia .36, Chile .02, Peru .03. The total land area of the sheet, with lakes and salars deducted, is in round figures 230,000 square kilometers, so that the average density per square kilometer is 3.6 (9.3 per square mile).

The population of Bolivia was officially estimated in 1918, and a comparison of the census figures for the four departments which touch the area is given below:

	1900	1918
La Paz	397,643	734,021
Oruro	86,081	137,336
Cochabamba	326,153	512,590
Potosí	323,615	515,458

Of this population the following proportion occupies territory covered by the La Paz sheet:

In the Department of Oruro—all
In the Department of La Paz—about four-fifths
In the Department of Cochabamba—about one-half
In the Department of Potosí—about one-fifth

The two most outstanding dense agglomerations (grade K, over 125 per square kilometer, or 324 per square mile) are those in the basins of Arequipa and Cochabamba[7] both of which represent agricultural populations practicing irrigation for the most part and living in a number of villages as well as in the two cities themselves. The latter, however, in common with all towns of over 4,000 inhabitants, other than mining centers, have been eliminated from the density calculation. The other areas of the highest degree of density are all about centers of mining industry. The lines have been drawn so as to include all the important mines about the centers. Thus we find a lower density on the nitrate fields than about Corocoro or Uncia, where the mines are more concentrated. The same tint appears in conventional rectangles over a few small towns which are not shown by special signs. The districts in which agriculture is important, although less intensively practiced than in the case above mentioned, are those which bear a population of grades H, G, F, E, and D—varying in density between 125 and 10 per square kilometer (324 and 26 per square mile). The grading within those limits

[7] In this connection see Isaiah Bowman: The Distribution of Population in Bolivia, *Bull. Geogr. Soc. of Philadelphia*, Vol. 7, 1909, pp. 28–47.

will be found to bear a close relationship to the water and soil conditions described elsewhere; and it should be noted that agricultural populations denser than 50 per square kilometer (grade F and upwards) are all to be found below an altitude of 3,000 meters, except on the shores of Titicaca where the climate is less rigorous than in the rest of the puna. The three lowest grades, C, B, and A (less than 10 per square kilometer), while they cover a few areas of sparsely settled and purely agricultural population, represent in the main the distribution of people who depend upon pastoral pursuits. On account of the wide range of the domestic and other animals upon which such people rely for their sustenance, very few areas are shown as uninhabited. They are restricted to the hot deserts, the salars, and those parts of the mountains and plateaus where soil and vegetation are reduced to a minimum. The northeast corner of the map is left blank owing to lack of data.

To make a proper comparison between the distribution of people in one area with that in another it is necessary to have population maps for both on about the same scale. Moreover, it is of greatest interest to compare regions where people follow similar pursuits—in this case agriculture, mining, and stock rearing. If, then, we had population maps on the same scale for parts of Colorado, the southern Ural, and New South Wales, to select from these continents, we might make some interesting deductions; but for the present we must be satisfied with two maps, of Wallachia (Rumania[8]) and Sicily,[8] both of them long-settled agricultural regions. In Wallachia, which contains something over one-third of the land area of the La Paz sheet, the population as a whole is much denser; but we find examples of most of the grades represented on our map. Thus the steppes east of Bucharest and the Carpathian forests correspond generally to grade C. The great contrast appears when we note that while the Bolivia grades E and K are limited to the few closely cul-

[8] Emmanuel de Martonne: Densité de la population en Valachie en 1899, 1: 1,200,000, *Bull Soc. Geogr. Romina*, Vol. 23, 1902; and Attilio Mori: Densita della popolazione in Sicilia nell anno 1911; scala 1: 800,000, *Memorie Geogr.*, No. 36, Firenze, 1920.

tivated spots about Arequipa, Titicaca, Cochabamba, etc., these grades are found all over the plains of Wallachia; and several of the valleys there support wide belts of more than 200 people to the square kilometer.

Sicily would fit roughly into the corner of our map northeast of the Cordillera Real, and its average population density is higher than grade K. Actually it has a number of areas supporting more than 500 people to the square kilometer and only a few small spaces with less than 50.

Such comparisons are useful if only in causing us to reflect upon the remoteness of this Andean region from the great world centers of population from which it might be more closely peopled, as well as upon its great altitude and other physical features which will certainly prevent it ever attaining such densities, save in the most favored spots.

The arrangement of population has of course undergone a number of modifications in the past. We have seen that at one stage of the prehistoric period Tiahuanaco was a great center probably maintained by a food supply from distant provinces. Otherwise the people who were dependent upon the llama and alpaca were probably more evenly distributed on the plateau than at present, and only small numbers lived in the marginal valleys. With the coming of the Spaniards in the sixteenth century great changes took place in a short time. The lodestone which brought the *conquistadores* into the region was the mineral wealth, and the opening of numerous mines led to a concentration of population in regions hitherto very sparsely occupied. The development of these mining centers is treated below; but we may note here that the Spaniards in flocking to the mines took many Indians with them, either as impressed laborers or free workmen. The new overlords were not long in control of the land before they took advantage of the presence of sedentary agricultural Indians and secured extensive grants of land (*encomiendas*) with serfs attached. Many of them settled upon these estates to enjoy the ease of life and the comforts which such a system of land tenure brought them. Thus new centers of popu-

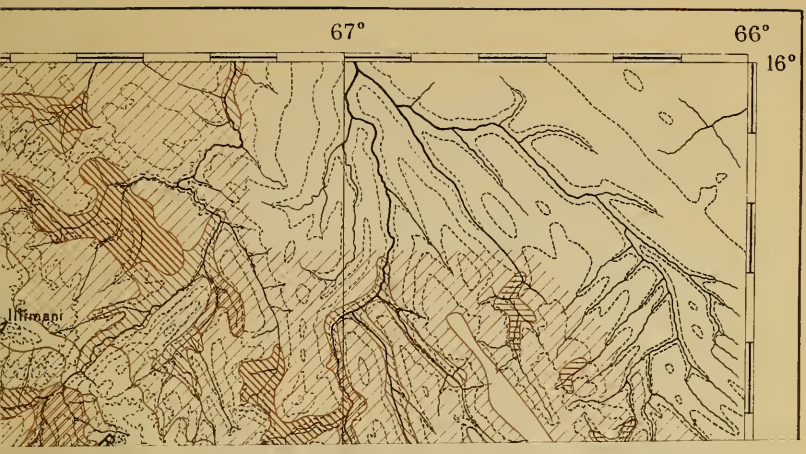
lation were formed, located as a rule in the valleys of the eastern Andes and the irrigated parts of the Pacific slope. For it was there that the Spaniards found the climate most suited to their comfort and to the animals and plants which they introduced from Spain. This led to the enhanced importance of the valleys and to the increase of their population. The new era was marked by the foundation of many valley towns such as Cochabamba, Inquisivi, and Quime.

The redistribution of the population was also undertaken by the enactment of measures intended to reorganize the newly acquired territories somewhat on the model of European countries. The scattered nature of the Aymará settlements[9] was not suited to the purposes of the Spanish Government, which wished to secure complete political control over the Indians in order to convert them to Christianity, to induct them into the ways of European civilization, and to collect a small tribute from them. Consequently the Viceroy, Don Francisco de Toledo (1569–1581), issued orders that all Indians should be compelled to gather together and to live in properly organized towns. While this order was not carried out fully, it brought many of the Indians into larger settlements and subjected them to the more complete authority of the colonial officials. Many, however, continued to live as formerly, either independently or upon the estates of the Spanish *encomenderos*, who generally opposed the reduction of the Indians to towns, being loath to see their serfs transferred from their properties. This was particularly the case among the hills and valleys of the eastern Cordillera, where most of the Spaniards had established their rural holdings. About Lake Titicaca and along the piedmont at the eastern border of the Altiplano the Indians became congregated in a string of relatively important towns.

Upon the western slope of the Maritime Cordillera there also grew up a number of Spanish towns, founded usually upon the sites of ancient Indian settlements, since few of the widely separated oases along this desert slope had not already been

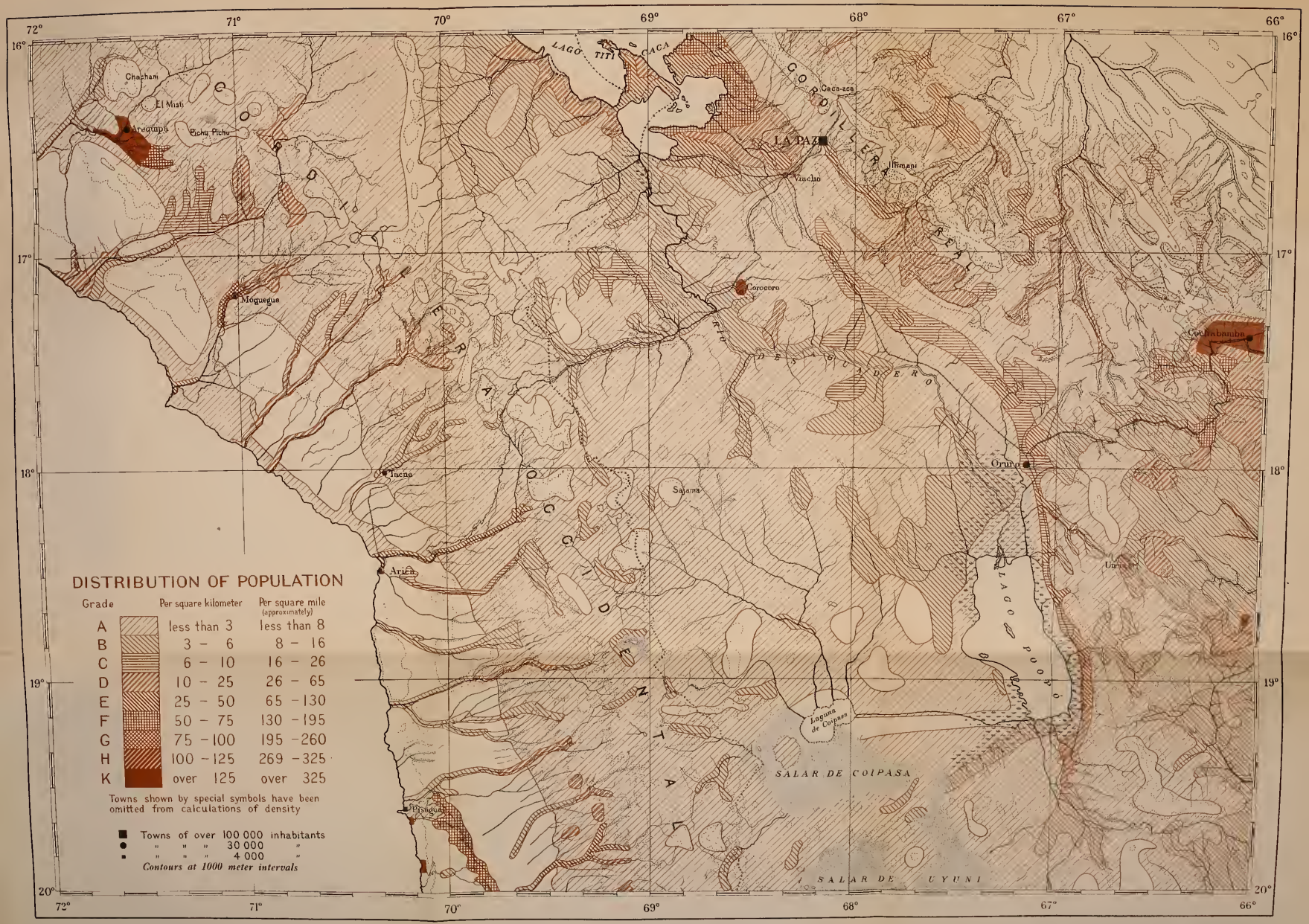
[9] See Appendix A.

Plate I



LA PAZ

Plate I



DISTRIBUTION OF POPULATION

Grade	Per square kilometer	Per square mile (approximately)
A	less than 3	less than 8
B	3 – 6	8 – 16
C	6 – 10	16 – 26
D	10 – 25	26 – 65
E	25 – 50	65 – 130
F	50 – 75	130 – 195
G	75 – 100	195 – 260
H	100 – 125	269 – 325
K	over 125	over 325

Towns shown by special symbols have been omitted from calculations of density

■ Towns of over 100 000 inhabitants
● " " " 30 000 "
▪ " " " 4 000 "

Contours at 1000 meter intervals

Scale 1:2,000,000

Kilometres 10 5 0 10 20 30 40 50 60 70 80 90 100 110

Sea miles 10 5 0 10 20 30 40 50 60

English miles 10 5 0 10 20 30 40 50 60 70

occupied by aboriginal agriculturalists. The Spaniards, well accustomed to an arid country and the use of irrigation, found these west-coast valleys, with their warm climate and fertile soil, choice sites for vineyards, olive orchards, and fields of cotton, cane, and wheat. In spite of the severe handicap of destructive earthquakes, these valleys soon became centers of European population. The Indians were reduced to serfdom upon the estates of the invaders, or were crowded out of the valleys and forced into the colder, less productive grasslands of the higher slopes, where they eked out a miserable existence from the small patches of tillable land or from the droves of llamas and alpacas which could be pastured at these heights.

Along the coast itself, too, there grew up a number of ports, most of them small, since no good harbors are found on this section of the Pacific littoral. The Indians had been little accustomed to navigation in these waters. Coastwise traffic was almost, if not entirely, unknown among them. Hence they had no ports of any importance. The Spaniards promptly founded a line of ports as the exploration of the coast advanced, and before many decades had passed there appeared a series of these, a formal port or a *caleta* (cove or bay) being established at the mouth of almost every valley. Sometimes a town grew up about these landing places; but more often, because of the utter aridity of the coast, the towns were built a few leagues inland, where both water and fertile soil served to support the inhabitants.

In later years, chiefly in the following century, even the towns that had been built upon the coast were often moved inland, for fear of the English privateers which frequented these waters and because of the dread of "tidal" waves that sometimes accompanied the earthquakes. This resulted in the existence of pairs of towns; a little port at the seashore and, inland a few leagues, a thriving agricultural settlement—the two linked by a road leading up the dry river course. Of such twin towns the most notable in the area we are discussing were Arequipa and its port of Quilca (beyond the limit of the map); Moquegua and

Ilo; Tacna and Arica. These valley towns while primarily of agricultural importance also served as the last way stations for the silver that was being shipped from the mines on the high plateau to the coast and thence to Lima (the viceroyalty capital) or to Spain via Panama.

The agricultural occupation of the land by whites also resulted in a partial zoning of the two races. The Spaniards who settled upon the land, as already indicated, sought out the districts where the climate was best suited to their requirements. From such districts the former Indian occupants were crowded out, or such as remained became gradually absorbed into the growing population of mestizos. Only the great expanse of the Altiplano, and the higher ridges between the valleys were left to the native Indian population. Thus the high valleys from 2,500 to 3,000 meters became largely European in racial character and in culture, while the regions above the 3,000-meter contour remained distinctly aboriginal in both. The exceptions to this were the mining centers, generally located at high altitudes. These, though composed in large part of Indian inhabitants, were organized on a European model and became more and more European in character, thus forming islands of white or mestizo residents among the prevailingly Indian population of the higher regions.

The mixing of the Spanish and Indian races which took place in these Andean highlands is in contrast to the process which went on in most of the lowland countries of both North and South America, where a war of extermination was carried on between the whites and the Indians and where the latter were either annihilated or were driven back before the whites into the interior parts of the country. Upon the plateaus both of the Andes and of Mexico, where the Indians were sedentary and firmly attached to the soil, the Spaniards came in as a race of masters, subjugating but neither exterminating nor driving out the natives. The fact that the conquerors seldom brought their women with them led to the growth of a mixed race which very soon outnumbered the Spaniards themselves. Since a number of

negro slaves had been brought in with the conquerors and also made alliances with Indian women, there grew up as well a smaller but important element of mixed negro and Indian blood. This mingling of races and the clearly drawn lines of social demarcation produced a number of slightly differing racial groups. There were the Spaniards, born in Spain; the Creoles, of pure Spanish blood, but born in America of parents who had virtually severed their ties with the homeland; the mestizos, children born of Spanish fathers and Indian mothers; the *mulatos*, born of white and negro parents; and the *zambaigos*, or *zambos*, descendants of Indian and negro parents. As the time passed, the blending of these various groups brought about still other combinations, each of which received a separate name, until there resulted the greatest variety of racial types.

Mode of Life

By far the greater part of the population is still living almost entirely on the produce of the country itself, and as regards physical requirements these people are more or less in the condition in which their ancestors were found by the *conquistadores*. Let us therefore analyze briefly these simple needs and see how they are met. The three concrete demands of peoples in an early stage of culture are food, shelter, and clothing; and as soon as the value of exchange is realized some means of transport becomes imperative. Long before the Spanish Conquest the natural resources of the land—and indirectly of the sea—had been fully exploited to meet these needs in an entirely independent manner; and, moreover, the rulers at least were maintained in a state of affluence, so that luxuries were already known and procured.

Food

The period at which the Collas and Quichuas became sedentary peoples must have been very remote; and ever since their settlement they must have been primarily occupied with pastoral and agricultural pursuits, their food being furnished by the soil.

The primitive and native food staples still form the main portion of the Indians' diet throughout the land. Thus the natives of the puna subsist almost entirely on potato, oca, dried beans, the grain of quinoa (*Chenopodium quinoa*) with *ají* (capsicum) ground up as seasoning, and a certain amount of maize brought from lower altitudes. It is noteworthy that, unlike the inhabitants of other high plateaus, the Andean natives do not make any extensive use of milk and its products, although these might presumably be procured from both llama and sheep. The potato is alternately frozen and thawed till the water is expelled, leaving a shrunken, light, and corklike substance known as *chuño*. Their food thus consists largely of carbohydrates, with protein derived chiefly from the beans. Sugar and sweet stuffs play no important part in the diet of the plateau Indians. In the past probably the only sweet fruit available was that of the cactus, which they still eat with relish. Animal foods are eaten only on rare occasions; but it would seem that, when hunting was a commoner pursuit than it is now, meat played a larger part in their diet. The cold climate, however, would seem to demand a greater consumption of fats or oil than exists, and it may be noted that lard, when sold in the towns, finds a good market. Around the shores of Titicaca fish is eaten; but the greater part of the catch is marketed in La Paz, a certain amount being dried and sent farther afield, as for instance to the valleys of the Yungas, where it is one of the main items offered in exchange for coca and fruit. It is said that fresh fish from Titicaca, as well as from the sea, was sent to the Inca's table at Cuzco by means of a system of relay runners (*chasquis*) which he maintained. At the time of the Conquest the settlements about Titicaca were recognized as amongst the most prosperous in Peru. It would appear that the fisheries were chiefly responsible for this. The chief significance of maize to the plateau Indians is as the basis of *chicha*, an alcoholic beverage prepared from the fermentation of the grain. This drink, which is the commonest form of alcohol in use, is responsible for much of the drunkenness, habitual among the Indians but most apparent during the excesses of the feast

periods. But it is rather on the purer alcohol (*aguardiente*) brought from the cane fields of coast and Yungas, that they rely, at the fiestas, to obtain the desired excitement and subsequent oblivion. Salt, a necessary ingredient of the diet throughout the entire region, is found in the salars in unlimited quantity and is one of the standing elements of internal trade. A curious habit amongst the Aymarás is the eating of clay mixed with their food. Apparently the only purpose it serves is to delay digestion and give a sense of repletion.

On the Pacific slope maize must long have been the chief staple, as indeed it is today, although fish has always been eaten in the coastal villages. In the districts settled by the Spaniards wheat, barley, and alfalfa were introduced from Europe. The first has ever since been the chief staple of the whites and is used to a more limited extent by the Indians of these parts. Barley has been widely cultivated, even on the plateau, where it does not usually ripen but is used for fodder and straw. Apparently in ancient times there was no such variety of fruit and vegetable here as there is now that the native products have been supplemented by those introduced both from Spain (see p. 113) and from the Yungas.

In these valleys of the eastern Andes the indigenous *yuca* and banana still supply starchy foods, which are supplemented by maize and a number of tropical fruits. Here again the variety of products has been greatly increased by the Spaniards; but the foodstuffs such as coffee, cacao, and cane sugar are mainly for export to the plateau for use by the whites and cholos. The savage Indians of the lower valleys, however, are hunters and fishers and so mingle a vegetable diet with game. Cattle, introduced from Spain, are kept in the clearings of the lowland. The dried meat of these, known as *charqui*, like the biltong of Africa forms a common food of the mestizos, especially when traveling.

Shelter

Climatic control is reflected in the type of dwelling throughout the region. In the coast lands protection is required against the

sun's rays but not against cold or rain. On the plateau the maximum shelter from wind, rain, and snow is sought. In the Yungas adequate cover from heavy rain as well as shade have to be provided. Generally speaking, therefore, the houses of the coast and the Yungas are more frail than those on the plateau; but in the Yungas, as well as in the Puna, roofs have to be well constructed. Throughout the entire area Indian dwellings with few exceptions are of one story, and on the Pacific slope this is true of almost all habitations, even in Arequipa, for people live in constant and well-founded fear of earthquakes. Arequipa provides an exception to the general frailty of structure on the Pacific slope because it commands a remarkably fine building stone—a volcanic breccia—easily cut and dressed; and many of the older houses are beautifully ornamented with carving. Additional strength in construction is often obtained by doming the roofs and ceilings. In other towns and villages the building materials may be adobe, stone if to hand, or simply branches plastered with mud. Roofs are thatched with various materials, often the desert grasses. The chief change in recent years has been the introduction of corrugated iron for roofing and even for walls.

The ruins of Tiahuanaco contain some of the world's finest example of masonry. Each of the blocks of hard lava, many of them of immense size, has been shaped and smoothed so that it fits its neighbors accurately and without mortar. We have seen that the architects and builders of this prehistoric city are believed to have been Aymarás. It is, therefore, not surprising that their descendents still furnish accomplished masons, when required, for government structures, although they have lost the consummate skill of their ancient forefathers. Their own dwellings are solidly built though rude. Where stone is used the modern Indian does not take the time to trim the frost-broken blocks which are abundant everywhere but uses mud to bind them, and in many villages adobe has completely supplemented stone (see Figs. 30 and 31). In the Cochabamba district the houses are often round in plan. The primitive Chipayas (Urus)

FIG. 30—Uru Indian woman grinding quinoa in a sheepskin. The house is of mud with a thatch of reeds secured by grass ropes to pegs in the wall. The sack contains llama dung (*taquia*) for fuel. The water jar is made of clay dug from a bank near by.

FIG. 31—Indian dwelling in the high country west of Lake Titicaca, representative also of much of the high pasture of the Eastern Cordillera. The occupants are shepherds, and the stone enclosure is a corral for animals. These hill slopes, which are mature, are covered mainly with ichu grass, the material with which the roofs of the stone houses are thatched.

north of Lake Coipasa build adobe huts of the beehive pattern, with or without a thatch of reeds. The walls everywhere are thick; there are few windows, and these are seldom glazed. Owing to the scarcity of timber from which boards can be cut, a wooden door is a rarity (if we except those made of the split stems of cacti), a stretched hide often serving the purpose. On the highlands, roofs are thatched with puna grass or reeds, and chimneys do not exist. The family spends much of its time in the yard—working and cooking there, for warmth normally is to be found without, in the sun, rather than within the house. About the dwelling there are usually several smaller buildings for storage, and also corrals for various animals enclosed by dry stone walls. The adobe house is the rule in the towns—even in La Paz, but the roofs there are of red, curved tiles. These, however, are gradually giving place to the corrugated iron of commerce. A striking example of the difficulty of procuring wood and iron in highland Bolivia is furnished by the telegraph posts which often consist simply of rough pillars of stone or adobe or the crooked, slender stems of valley shrubs. Household utensils, as is to be expected on the plateau, are the simplest, and even these are treasures, so scarce is material—especially wood—for their replacement. Llama bones are still largely utilized in making household implements.

In the Yungas, wooden posts and laths form the walls of most of the houses, the frame being filled in with banana leaves, ferns, or other dried vegetation. In the higher villages, stone is often used, or a combination of stone and wood. The houses of the whites are frequently two-storied adobe structures with an outside stair. Roofs are always well thatched and have wide eaves to carry off the rain.

Clothing

The contrast of highland and lowland again is represented in the clothing of the inhabitants, cotton in the warm lands, wool in the cold highlands. Cotton is native and is still grown and woven in the coastal valleys; but the garments of the modern

Indian are largely cut from the imported article. The need for warm clothing on the Andean heights was the main cause for the great vicuña hunts carried on throughout the Inca period—in which the captured vicuñas were usually not killed but were shorn and set free. Moreover, the same demand, as well as the need for a beast of burden, must have led to the domestication of the llama and alpaca and to the early perfection of the hand loom. Today the wool of the llama is less used for clothing; and indeed the animal is seldom shorn. Sheep, introduced by the Spaniards, now furnish wool for the bulk of the clothing, the alpaca wool being reserved for the finer garments and for export. The wool of the vicuña, which is now very scarce, can be woven to give a material as soft as the finest silk. During the Inca period vicuña fleeces were reserved for the exclusive use of the emperor and his household. While these wools are often dyed, a certain amount of design is possible while using only the natural wools—the black and white of alpaca, the usual brown or gray of llama, and the bright tan of huanaco and vicuña.

The costume of the plateau Indian is presumably the same today as it was before the Conquest: underwear of cotton, brought from the hot lands; loose woolen trousers reaching below the knee; and, in the case of the women, innumerable petticoats also of wool. The feet are bare save for leather sandals. The hat is of home-made felt on the plateaus; but in the warm lands this is replaced by a wide-brimmed straw hat. The men of the puna wear a closely fitting woolen cap under the hat. Fashion demands that natives of different localities shall wear hats of different pattern. The typical garment of the Puna is the *poncho*, or cloak, which is woven in one piece with square corners and a hole in the middle for the head (see Figs. 33 and 35). It is in the color and design of this that the inherent art of the plateau Indians finds its best expression. The limited vegetation of the puna provides a surprisingly large choice of dyes—eighteen such plants are known to science in Bolivia,[10] and the women have long since mastered the processes of their extraction, as they

[10] *Annuario Geográfico y Estadístico de la Republica de Bolivia*, 1919, p. 21.

have the crafts of spinning the wool and weaving it on their hand looms. When traveling the Indian as a rule carries ponchos of two weights, the lighter to be worn by day, the heavier by night. In the forests raw material for the loom is not limited to cotton; for there are a dozen other plants which provide fibers and are used for a variety of purposes.

Health

Every traveler in the high Andes is struck by the fact that while he, in common with the non-Indian inhabitants, suffers from mountain sickness, or *soroche* as it is called in this region, the Indians are immune. Most foreigners and the inhabitants with Spanish blood become more or less accustomed to life at high altitudes; but travelers who have time find it well to stop for a period at some station like Arequipa on their way up to the plateau, in order that the transition may not make too sudden a strain upon the body. It appears that in the thinner atmosphere of the high plateaus the oxygen content of arterial blood is lower than at sea level in all individuals—white and Indian alike. Apparently, however, the Indian is able to compensate for this on account of greater lung capacity. In the case of the Aymará this is accompanied by a chest abnormally large in height and width which is noticed by so many observers.

Endemic diseases seem to be few in the Central Andes. Probably the most serious of them is that generally known as *peste*, or *fiebre amarilla* ("yellow fever") which possesses symptoms akin to typhus and which breaks out at intervals causing great ravages among the Indians. The inhabitants of the Yungas valleys are subject to the curse of malaria, and while they also possess the source of the remedy, they can ill afford the cost of manufactured quinine or neglect its use. Goitre is a prevalent disease, and in fighting it the natives have long ago discovered one of the antidotes of modern medicine, iodine. The sufferers eagerly purchase dried seaweed from the Pacific coast, and it is doubtless the iodine contained in this which works the cure.

Both syphilis and gonorrhea seem to be very ancient diseases

in the country, and it has even been suggested that the former originated here. The chief reasons given for this are that diseased skulls and bones have been found in ancient graves, and that the alpaca suffers from a similar if not identical disease. The Indians have long treated syphilis with mercury brought from the mines of Peru. Since the Conquest the population has been decimated from time to time with epidemics such as smallpox, measles, and influenza. The plateaus so far have not been stricken with tuberculosis, but the Bolivians live in great dread of its introduction from Chile and Argentina where it exists.

Reck made an examination of vital statistics for Bolivia in 1846 and found an interesting variation in the death rate in different zones.[11] Thus in the Puna it was lowest, 1.97 per cent; in the Valles, 2.38 per cent; and highest in the Yungas, 3.70 per cent. He also found that there is great danger in childhood from birth to the end of the fourth year, five out of every twelve children dying before that age; but from then onwards the expectation of life is high, and there are probably many cases of Indians living to over a hundred.

Transport

The advantages of exchange must have early become apparent to the inhabitants of this region, and especially of the interchange of the commodities of plateau and lowland. The llama, then, as the only beast of burden, has been an essential feature of Andean economy from a remote period; and throughout the plateaus the wealth of the humble Indian may be judged today by the number of llamas or other animals which he owns. The llama has the great advantage over other beasts of burden that it is not subject to mountain sickness (*soroche*). Moreover, it needs only the roughest fodder and little water. Its flesh and wool can be utilized, and it is marvelously surefooted on the worst trails. But, on the other hand, as compared with animals of other lands, the llama does not carry a heavy burden, the load varying from 50 to 100 pounds. The animal is extremely

[11] Hugo Reck, (6) 1866, p. 304.

stubborn, and its pace is slow. Moreover, it is exceptional for a llama to live more than twelve years, and in many districts the average life period is much shorter. Since the Spanish occupation the mule and the ass have been added as carriers, while the ox has been introduced as the servant of the plow, an implement which itself was unknown before the Conquest.

More Complex Influences

With this brief statement of the concrete elements of life in the region we may with advantage review more broadly the life of the people in the various geographical zones of our region.

Hitherto we have discussed matters which affect all men alike when in a simple state; but to understand how people live today we have to bear in mind the complications introduced from time to time in their history. In the Andes stress must be laid upon two of these—the one economic, the other primarily social. The first is based upon a geographical fact—the mineral wealth of the country. The mining development and its consequences have had a far-reaching effect upon the people and the status of their countries. The second is not in itself a geographical fact, although geography has much to do with its effect in different districts. I refer to the peonage system introduced by the Spaniards, with some slight background from the Inca régime, by which the bulk of the Indian population is to a considerable extent in bondage to the whites or the mestizos who are the owners of the land. As the mining industry, economically important though it is, affects only the smaller proportion of the population we may leave it for later treatment and turn to the social basis of agriculture and stock raising.

Ever since the arrival of the *conquistadores*, when that portion of the land allotted to the service of the Inca and of the sun became alienated to the Spaniards there has been a constant absorption of land by their successors, white and mestizo. Almost the only land now in the hands of the Indians is that held by the communities; and the community Indians are now virtually the only free Indians in the region. It is they who furnish

the carriers of the Andes and the laborers of the mines and the railroads. Most of the fishing is in their hands; and the Callahuayas, or traveling herb doctors of the Cordillera Real, are community Indians.[12] In fact we have to go to this much-reduced class to see the pre-Conquest life of the Aymará and other stocks in all its phases. The community lands are now restricted to the least desirable areas from the point of view of the white man—to districts off the main routes or with poor soil or specially inhospitable climate.[13]

With these exceptions it seems probable that there is no part of the region where the land is not claimed by some individual or group, and where the inhabitants are dependent upon the owners of the estates. This does not mean, however, that these Indians are serfs but simply that by law they are bound to give some service—mostly in cultivating the owner's land. And it is largely due to the conservatism of the Aymará that the law based upon long-established custom is maintained. Indeed in most cases, at least in highland Bolivia, the landowner would not dare to demand more service than custom determines, and he generally considers it wise to take the service at the time and in the manner ordained by custom. Violation of the custom by proprietors is always liable to lead to a revolt of the Indians. The estates are of variable size, probably being larger on the less productive areas. They are generally distributed in such a way that each contains a proportion of land suitable for various crops and on the plateau a certain amount of better pasture fit for alpacas and a much greater area of poor pasture—mainly ichu grass—suitable for llamas and sheep.

In the agricultural life of the country, then, there are four classes involved: the community Indian, who is self-sufficient and who ekes out a living derived from primitive agriculture on poor fields by fishing, carrying, or hiring his labor to the mines; the landed proprietor—of white or mixed blood—who is generally

[12] On these interesting people, whose home is just north of the La Paz area, see Gladys M. Wrigley, (144).

[13] On this and other aspects of land tenure see George McCutchen McBride, (143).

an agriculturist only by proxy, living in a town and visiting his *finca* for the harvest and the sowing; the *mayordomo*, generally a cholo, to whom the proprietor delegates his authority and who is in effect master of the farm; and, lastly, the *colono*, or peon. The colonos, or Indians bound to the estates, are by far the most numerous class. They receive small patches of land in the estate —about three hectares on the average—to be worked for their own use, and these in common with the owner's land are reallotted from time to time. The number of colonos families on each estate varies with its size and character; for instance an estate of 5,000 hectares near Oruro has sixty families, while on another, in the Cochabamba basin, 750 hectares are worked by 150 families. The price of a farm generally varies according to the number of Indians upon it rather than to its extent. The colonos remain on the land in case of transfer of ownership.

Examples of Peasant Life and Utilization of the Land

We may now examine in greater detail the manner in which life is controlled in different situations by the physical environment and by the social system of the country. The map (Pl. II) showing the distribution of different types of land utilization will be found to illustrate the examples.

Let us first consider a typical finca on the Altiplano. It is centered round a small alluvial fan at the foot of one of the low ridges which rib the plateau. It extends, on the one hand, to the banks of the Desaguadero and includes a wide stretch of the hills as well as of the pampa between. It is bleak and wind-swept. The most sheltered spot is occupied by the houses of the owner—rarely occupied by him—and of the mayordomo. About these there is a plantation of eucalyptus—the only trees visible on the wide landscape. A small church, distinguished from other buildings mainly by its size, stands near the center. It may be used as a granary; but at least once a year it is visited by the *padre*, and the entire population comes to service. If the farm be called San Antonio, the priest will probably choose St. Anthony's Day for his visit. The houses of the colonos are dotted about within

a short range of the main farm buildings and enclosures. The alluvial fan is the center of things, not because it is capable of permanent irrigation—as it would be in a better watered area—but because the soil is thicker and because there are permanent wells around its margin. Near the Desaguadero and along the flat bottom of a wet-weather tributary there are strips of pasture of a fairly good quality. Elsewhere on the flat pampa the light soil is scarcely concealed on the numerous fallow fields, and the fields under crops are rather widely scattered. The hills show many outcrops of bare rocks and stony hollows with patches of tola bushes, puna grass, and other humbler plants, sometimes thick but mostly isolated, giving a speckled appearance to the hillside.

The fields and pasture land of the Indians are not distinguishable from those of the *patrón*, save that they do not occupy the best land. The limits of the finca are not clearly marked on the ground except on the good land, where a rough stone wall is the boundary. Heaps of stones gathered from the fields dot the pampa, and these are often placed at the corners of fields.

Each family knows exactly what is expected of it by the proprietor. Two days in every week they must work on his fields bringing with them their own oxen for plowing (see Fig. 32). Moreover, each year the group as a whole has to designate one or two of their number as herdsmen as well as to maintain for the master a house servant (*pongo*)—in this case probably in La Paz—who is changed each week. They also deliver to his house so many loads of fuel, tola shrubs or taquia (dried llama dung).

Throughout the year a few men find a continuous occupation in herding the sheep and alpacas. In this case the latter are owned only by the master, for the area of short, green grass required by alpacas is small, and the Indians are not allowed to use this pasture. In the summer at a convenient week the flocks will be corralled and shorn, and the Indians, after keeping what they need of the wool, will carry the remainder of their own share as well as all of the patrón's to the market at La Paz or Huaqui, using their own asses or llamas.

FIG. 32—Colonos (peon laborers) plowing and sowing on a farm in the La Paz valley.

The average temperature of the soil here is low, and its recovery after cropping is slow; so the fields lie fallow—in some cases as much as twelve years—before recultivating, the weeds which spring up being used as pasture. In such land manure is very valuable, and every particle of dung and ashes which can be gathered after the fuel has been provided for is put upon the fields to be cultivated. But in this farm they must use much taquia as fuel, for both tola and yareta are scarce or their sources distant, and they grow very slowly.

Winter is the slack time, when clothing and implements are made in the cottages, while the patrón takes advantage of it to have ditches dug, or building and other odd jobs done. But when the spring rains begin in September or October all get busy with the sowing of quinoa and the planting of early potatoes and ocas. With all of these crops the farmer need have no fear of damage from frost, for they are natives of the Puna, and most of the many Andean varieties of potato are also remarkably immune from pests. About November other varieties of potato are put in to give a later harvest. With the human food supply for the year thus provided for, the Indian thinks of his beasts. We have seen that pasture here is poor and thin. The owner may have taken care to have part of his moist land sown with alfalfa which will meet most of his requirements. But for the Indians another crop must be sought, and it is found in barley. This cereal will ripen only in sheltered spots near Lake Titicaca, but if sown before the height of the summer rains it may be cut while green in the autumn for fodder purposes. This crop is scarcely sown when the first potato harvest is at hand. The owner's crop has to be carried to market, but most of the workers' yield is turned over to the women who are occupied as opportunity offers with the preparation of chuño, which takes two or three weeks. The potatoes are first put out to be frozen through, and thereafter in turn are tramped with the feet in water, dried in the sun and again tramped in water to remove the skin. The starchy product will then keep for years.

There follow in quick succession in the autumn a second

potato harvest and the cutting of the fodder barley and the quinoa—generally in May. The quinoa is cut just before it is fully ripe to prevent loss of the grain. The heads are threshed by primitive flails and winnowed by throwing in the air. The conclusion of the agricultural year is the plowing carried out shortly before the sowing, by which soil is merely scratched to the depth of a few inches by the ancient wooden plow of Spain with or without an iron tip. Such is the annual routine, but there are notable interruptions to all work at the fiestas as well as after the principal harvests. When occupied with digging potatoes every one is notably happy, and much jollification takes place. The chief religious festivals are celebrated by the entire population. Attendance at mass in the village is merely an incident preceding traditional revels which include dances of pre-Christian origin, in which the dancers wear masks and gaudy trappings of skins and feathers. Dances and drinking bouts alternate and are kept up for an entire week in the case of the greater occasions such as the *carnaval*, thus putting a complete stop to the autumn labor, important though it is. That this traditional and spasmodic drunkenness is so important and universal a feature of the high Andes may be due to the rigor of the climate and extreme monotony of life. The visits to the market furnish opportunity for the purchase or bartering of alcohol or more commonly aguardiente from the Yungas or coast, as well as of coca which the Indian chews more or less as other men smoke tobacco, so that every family is well stocked with stimulants when the fiesta breaks out.

The type of life on the fincas throughout the Altiplano varies but little from that described. These farms are widely scattered over most of the plateau and cluster more closely where there is better soil and a more certain supply of water or a milder climate. On Plate II this feature has been shown by distinguishing between the main area described as "pasture with intermittent agriculture" and a number of smaller patches of "agriculture more or less permanent." This means that in the agricultural fringe round Titicaca and along the piedmont of the eastern

FIG. 33—Procession of Aymará Indians at a *fiesta* in La Paz.

FIG. 34—Abandoned artificial terraces known as *andenes*, a common hillside feature throughout the Central Andes. They are an evidence that greater numbers of people formerly practiced agriculture, a change frequently due to migration to the towns and mines and to extension of pastoral land.

Cordillera fields are closer together, and a smaller proportion of them are fallow at one time than out on the plateau. Moreover, on the alluvial fans east of Lake Poopó a limited area is under irrigation at least for part of the year, and this of course renders the land more valuable. In the La Paz sheet it has not been possible always to distinguish fincas from villages; and, furthermore, it is probable that many of the smaller farms are not located.

The village of the plateau is for the most part the domain of the cholo who is engaged in trade, and the number of them who live there as a rule is small, though such villages often present an animated scene owing to the presence of Indian visitors from the surrounding farms, particularly on market days or at religious celebrations.

The slopes of the hills about Lake Titicaca and the Altiplano as well as the ridges which rise from the plateau are marked in many places by parallel terraces known as *andenes* (see Fig. 34). These are clearly artificial and have been made to retain the soil and facilitate the cultivation of steep slopes. But they are now almost entirely abandoned; and this fact has often been quoted as evidence that the population of the Central Andes was formerly much greater, the decrease usually being attributed to diminished rainfall. But it would appear unnecessary to postulate any such climatic change to explain abandoned andenes. The modern development of mines, railroads, and towns has drawn large numbers of the Indians from the fields, and the hillside farms would be the first to be deserted, since the maintenance of the terraces demanded considerable labor. Furthermore, much of the land passing from small to large owners has been found to give better results when devoted to pasture.

Plate II shows a large proportion of land under irrigation in the high valleys of the western Cordillera, much of it over 4,000 meters in altitude. The information upon which most of this is based was derived from the Chilean boundary surveys, and while the representation is presumably accurate in extent it may be somewhat misleading if we fail to remember the altitude.

The population density in these mountains is low, but the flocks are large, and the colored areas on the map for the most part do not represent irrigated crops, but rather pasture improved, in part artificially, by waters from the melting snows of the high peaks. An interesting example of this type of land has come to light.[14] The small group of Chipayas—or Urus—living north of Lake Coipasa have developed an industry called forth by the demands for lard by the nitrate workers of the coastal pampas. The Chipayas, by damming the Lauca River, have made sufficient pasture to feed herds of swine; and from these they obtain the lard which they carry down to the coast for sale. There appear to be numerous community Indians in this Cordillera, and information is lacking as to the extent of occupation by Chilean landowners. Probably the grazing limits of the various proprietors and communities are more fluid here than anywhere else in the region. Even the international boundary is frequently disregarded by the shepherds of the Bolivian side, who are naturally tempted by the greener hollows to the west. A considerable amount of seasonal movement of flocks takes place between the high pastures and the lower valleys on the Chilean side, but here again exact data are lacking. Cattle are kept in small numbers about Lake Titicaca, and an important source of food for these is the aquatic weed growing in the shallow water. Through long habit of diving for their dinner these animals have become almost amphibian, and they spend much of their time in the water.

The annual round of the community Indians on the Altiplano is more varied than that of the colonos. As has been pointed out the free Indian's life today approximates much more nearly to that of the pre-Conquest Aymarás than does that of their peon brethren. The agricultural year makes the same demand in both cases, but the free Indian has time to make use of other opportunities of gaining a livelihood. There are the chinchilla, viscacha, and vicuña to be hunted; and in this they display infinite patience, for when they have carried the skins down to

[14] Arthur Posnansky, (119).

FIG. 35—Fishing *balsas* on the shore of Lake Titicaca. The rafts and sails are made of reeds bound with grass rope. The Aymará fishermen are wearing the clothing characteristic of the high Andes—poncho, jacket, loose trousers, cap, and felt hat, all of wool, and sandals of rawhide. On the shore is a bundle of tola bushes for fuel. The hills exhibit typical mature surfaces.

Tacna, Arequipa, Puno, or La Paz they will receive payment which to them is almost a king's ransom. There is fish to be caught in Lake Titicaca, and here their community organization comes into play; for the most effectual method demands the collaboration of a number of boats dragging a net between them. But fishing from individual boats is also carried on, both the net and the spear being used. The scarcity of wood on the plateau is evident from the nature of the Titicaca fishing boats, or balsas, built, save for the mast, entirely of reeds bound together, and the sails are likewise made of reeds woven like a mat (see Fig. 35). Fishing with the spear is carried on in shallow water, the boat being propelled by a long pole. The wood for these and for the masts is brought from the Yungas. The fishermen of the Pacific coast also employ the reed balsa propelled by paddles, and examples still exist there of the floats in common use at the time of the Conquest made of inflated sea-lion skins, which the fisherman bestrides. But the wooden fishing boat of Mediterranean type has been generally employed since the Spaniards settled on the coast; and, while even this is too primitive a craft with which to develop an up-to-date fishing industry commensurate with the immense supply, yet it is much more useful than the balsa. These boats are now also constructed on Lake Titicaca from imported boards. On Titicaca there are no better practical meteorologists than the fishermen. They are accustomed to predict breezes which will take their boats out in the evening and bring them back in the morning in time to get their catch to market in La Paz the same evening.

The community Indians of the southern Altiplano can occupy the winter months in gathering salt from the great salars, packing it on their beasts, and hawking it round the country. Everywhere there is the demand for fuel, the taquia of the farms and vicinity is often insufficient, and the best growth of the resinous yareta is generally far from the settlements and at higher and higher elevations. It is the free Indians who gather and sell it, incidentally pulling it up by the roots and so preventing its spread. The *arriero*, as the carrying Indian is called, is a feature

of the landscape on every road and trail, never riding but leading or driving his little caravan of llamas, asses, and occasionally mules. He is indispensable to trade, and till within the last few years he was essential to the export of minerals. It is to the Indian community that the mine agent, the railway engineer, and the public works officer must go for their laborers, since the colonos are not available. And this means frequently a temporary draining of population from long distances.

In the districts more favored climatically than the plateaus and Cordilleras—the Cabezas del Valle, the Medio Valle, the Yungas, and the coastal valleys—life differs in many respects. In the first place, of community Indians there are none; the land is too valuable. There are, it is true, in some parts—in the Cochabamba basin for example—other free Indians engaged in agriculture who farm their own land. But, generally speaking, these regions are occupied by valuable fincas worked by numerous colonos. Secondly, since the climate permits the cultivation of a much greater variety of crops, agricultural operations are more complicated; and, while modern machinery and implements are still rare, the more numerous alternative crops present opportunity for development of greater agricultural skill than in the zones of the Puna and the Puna Brava. It is noteworthy that the most accomplished farmers are often found amongst these peasant proprietors, a fact which recalls the dictum of Arthur Young in 1789 when visiting peasant farms—then rare—in France, "the magic of property turns sand into gold." In the coastal valleys irrigation is essential, and it is greatly valued in the valley heads of the Eastern Cordillera; so that in both regions a new complication is introduced in the distribution of water; and water rights are a constant source of broken heads and of litigation.

In the zone of the Medio Valle is found the densest agricultural population of the area—about Cochabamba and Arequipa (see Fig. 36). To illustrate the valuable nature of this land with its fine alluvial soil and sufficient water we may note the composition of a typical farm near Luribay in the deep basin below the

FIG. 36—Farms in the Chili valley above Arequipa. The smooth surfaces of volcanic detritus, where not dissected by ravines, are cultivated land or pasture. The Chili valley itself is here under irrigation. The slope of El Misti appears in the left background.

Quimsa Cruz Cordillera and at about 2,700 meters altitude. The farm evidently includes some hill pasture, for it supports a flock of 600 sheep; but its real value rests upon ten hectares of grapevines for wine and a ten-hectare orchard containing 1,000 fig trees, 2,000 pear trees, and 800 trees of apple, peach, and that most luscious of all Andean fruits—the cherimoya. In addition, there are five hectares in alfalfa or other pasture supporting six cows, four oxen, and twenty-two horses, asses, and mules. This farm is worked by 101 families of colonos.[15] The majority of the fincas have a smaller proportion of fruit land and many fields of cereals; for not only does barley always ripen at these altitudes, but wheat, oats, and maize are grown, as well as large quantities of beans and alfalfa.

Another feature of this fine agricultural zone is the possibility of obtaining by irrigation several harvests of alfalfa, as well as reaping two different crops in the same year. For instance beans will be sown in May and reaped in July (midwinter), and then by immediate plowing and sowing in August or September a good crop of maize, grown under the summer rains, will be harvested in May. In the Cochabamba basin the irrigated land is mostly under maize, and the best crops come from the fields watered by streams carrying much silt. In such places the grain will yield as much as two hundred fold as compared with the forty fold return on unirrigated land. Moreover, no manure and no fallow time are needed on such land. The greater part of the unirrigated fields produce wheat and barley, the wheat giving a tenfold yield, the barley somewhat more. The ground as a rule is not manured and lies fallow for only two years.

In the Pampa of Arequipa, which is lower than the Cochabamba basin, the crops are similar; and there is a noticeable response to local climatic differences in the higher yield of crops, especially of maize, in the lower and more sheltered district of Tiabaya as compared with the environs of Arequipa. Similarly the colder winter of the higher section accounts for a difference of from two to three months in the time of plowing and sowing

[15] Karl Kaerger, (141), Vol. 2, p. 311.

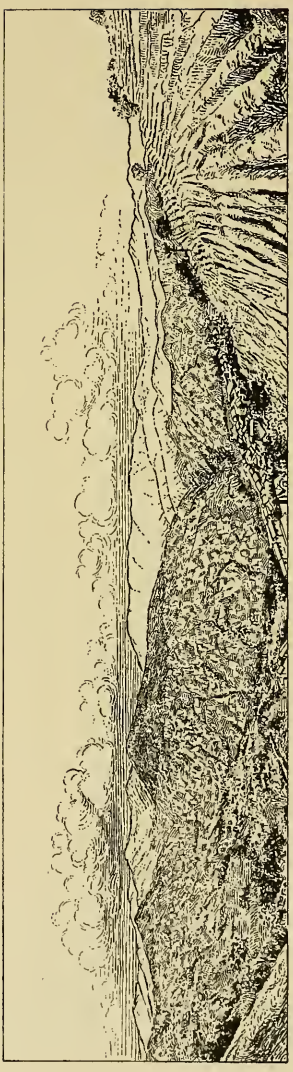


FIG. 37—Upper basin of the Río de Coroico in the Yungas, with coca and coffee plantations, and, in the foreground, the town of Coroico. Viewed from the east. Drawn from a photograph.

wheat and barley. Manuring is much more prevalent about Arequipa than at Cochabamba, and the Peruvian district has the advantage of being able to procure cheaply the guano of the coast.

The map on the scale 1:1,000,000 is rather too small to bring out clearly the real nature of habitable land in the Yungas; but study of Figure 37 will reveal the fact that valley floors are of very limited extent and that the wealth of the region is derived from the slopes. Moreover, this drawing, made from a photograph unfortunately too large for reproduction here, demonstrates better than any description the importance of the altitudinal zone in the Eastern Cordillera. The village in the foreground is Coroico, and we are looking westward towards the Cordillera Real. The summits of the range are hidden by clouds, and the even crest lines of the background represent remnants of the ancient peneplane surface lying to the east of the snowy peaks. The highest visible point is about 3,600 meters in

altitude. Coroico is at 1,725 meters, and the stream is running some 700 meters below it. Perhaps the most striking feature of the view is the upper limit of terrace cultivation following almost with precision a contour line as far as the eye can reach. The level of this is about 2,000 meters, and nearly up to this height everywhere the close-packed fields are coca plantations like those in the foreground. This land has once been forested, and we may note that timber still remains above the zone, climbing to the top of the nearest ridge but concealed by distance in the farther valleys. The upper Montaña was probably never so dense here as at similar levels on the outer slopes behind us, for the valleys in view form a rather sheltered basin.

This, then, is the coca belt of the Yungas, which represents the chief wealth of the Atlantic slope of the Andes. It winds about in the valleys and is more or less continuous from southern Peru to the Yungas of Cochabamba east of the map limit, never varying far from the altitudinal limits illustrated in the figure. The zone, however, is not everywhere so intensively cultivated as it is here, and the coca production is of distinctly smaller importance south of the La Paz-Bopi River, the chief centers of the industry being Coroica, Chulumani, and Irupana.

The climatic requirements of coca—warmth and moisture with a cloud shield from a blazing sun—are also those of coffee, and the two cultures are associated; but by far the greater area in the belt is under coca, and the coffee bushes are planted largely in hedges between the coca fields and along the paths. When the traveler, making his first descent to the Yungas, thinks of the immense benefit which the human race derives from the cocaines, extracted from the leaf of *Erythroxylon coca*, his journey becomes in a sense a pilgrimage to the birthplace of the precious drug; and, moreover, he can recall that the same zone is the home of the cinchona tree, whose bark provides another alkaloid and an equal treasure to mankind—quinine.

It happens, however, that the Yungas of Bolivia are no longer of first importance to the world in furnishing these precious remedies, for both plants have been introduced to southern

Asia, which now yields the greater proportion of the drugs. But coca is an essential to the life of the entire native population of our region, not as an anaesthetic but as a stimulant. The dried leaves have been a leading staple of internal trade since prehistoric times. No Indian will work or travel without his ration of coca, which he mingles with ashes of the quinoa and chews systematically three or four times a day. His nervous system is adjusted to this practice, and he cannot do without it. While the effect is primarily stimulating, the coca dulls the sensation of hunger.

In the coca belt we have an exception to the rule that free Indians do not occupy the valuable land. The bulk of the harvest is reaped by Indians who cultivate their own land; but the best quality of leaf is produced on the haciendas. In the view from Coroico we are struck by the paucity of isolated dwellings. Most of the workers are grouped in the village. We may note also the groups of trees scattered amongst the fields on the slopes. Some of these are merely original forest trees left for shade; but most of them are fruit trees, largely orange and cherimoya.

The Yungas Indian, then, is occupied throughout the year with his coca, his coffee, and his fruit—all of which when ready he will sell to the middlemen in the market of his village for export to the highland or beyond. To maize, sweet potato, beans, and other vegetables he devotes just sufficient land and time to supply his own limited needs. Although the Yungas are always moist, there is a seasonal rhythm in the agricultural year, for irrigation is not practiced, and the preparations of new plantations as well as the biggest harvests of the mature bushes take place during the heavier rains of the summer. The seed for a new coca field is sown in November in beds and covered with a layer of grass. Then as the plants spring up a low shade canopy of grass or banana leaves is raised over them. At the end of a year the foot-high plants are ready for planting out in the deep trenches of the field, and another year must elapse before the first harvest can be made. The life of a plantation (*cocal*) is from twenty years in the warmer parts to forty in the cooler

parts of the belt. The leaves are picked from three to four times a year, and female labor is the rule. The two big harvests are early and late in the rainy season, in November—Mita de Santos (All Saints)—and March. In June comes the third—Mita de San Juan, and, if the winter rains are plentiful, a fourth between June and November.

Similar preparations are necessary in planting coffee, but three or four years elapse before a yield. The three harvests fall, with some variation, respectively in October or November, January to March and May to July—the last being the heaviest. Coffee picking as a rule does not clash with the coca harvest. The drying of coca leaves and coffee berries alike is carried out on the stone-paved *seccador*. The Yungas coffee, which is famous for its aroma, is exported with the parchment covering still on the bean.

The above description of life in the coca belt accounts for the life of the largest number of people in our area east of the Altiplano. But both above and below this zone men live and in entirely different conditions. In a belt limited below by the coca fields and above by the talus slopes of the mountain core there are widely scattered haciendas, most of them centered on the narrow alluvial *playas* of the valley, but some of them on the flat-topped spurs high above the rivers. A little agriculture is practiced about these—maize and the temperate fruits in the valleys; barley, potatoes, and quinoa on the high spurs. But the belt is chiefly known for its cattle pastures. Where the forest thins out and above that on all the gentle slopes the grass is thick and good. The herds are small, and they graze untended where the topography limits their range naturally. This zone is one of the two sources of draft oxen and of beef, the other being the clearings and possibly also natural savana country of the hot lowlands. Where the natural forest—the upper Montaña—still exists, as it does almost everywhere south of the La Paz-Bopi River, it is the haunt of the cinchona gatherers. These Indians live a hard life in the dense forest. The best trees are found in the valleys between 2,000 and 3,000 meters altitude. All the bark which they cut they must transport on their own backs.

The remaining area to be mentioned lies below the coca belt. It is naturally forest, and the scattered population is grouped round isolated plantations or missions along the rivers. It is the upper limit of the Montaña, the forest whose natural resources of timber are scarcely tapped and where the rubber painfully gathered by the miserable *cascarilleros* has now but small importance in face of scientific cultivation elsewhere and of the enormous difficulties of export. On the farms, which are situated on the playas, or flat strips on the river banks, the patrón is the master of his colonos in a much more absolute sense than on the plateau. The finca is here a plantation in the accepted sense. Cacao and sugar cane are the main crops of the patrón. The products of these are easy of export either separately or mixed, as chocolate. Moreover, the patrón operates his own distillery and finds in alcohol his most remunerative commodity. In addition to these crops all the tropical fruits, including the pineapple and various bananas, grow with the minimum of cultivation; and the natives themselves need put very little energy into supplementing these by other food crops such as yuca and sweet potato.

In early chapters we have learned to appreciate a number of physical causes for the restricted nature of cultivated land near the Pacific coast. Topography, soil, and climate combine to limit agriculture to the narrow strips of the valley oases. Since the river water is the life blood of these, it follows that success or failure in raising crops depends upon its even distribution on the land; and here again physical conditions are modified by the historical circumstances of its occupation. It has been a case of first come, best served. The irrigable land is held almost entirely by *hacendados*, only the higher valleys remaining in the hands of Indian communities; and, since the first grants were naturally made for the lands nearest to the source of water, the proprietors with the longest line of landholding ancestors are often in effect the masters of the valley, the water rights of estates lower down being usually much less valuable. Recent changes have certainly been in the direction of equity in this matter; but it would appear

that the irrigable land as a whole could be made more productive if the interests of all were considered equally. The valley oases within the limits of our sheet are farmed almost entirely by Peruvian or Chilean landholders; and it would seem that with the limited amount of water and of initiative at their disposal the population is sufficient to provide the requisite labor. It may be noted, however, in passing that such is not the case in the Peruvian oases farther north where many foreign proprietors, in striving to develop the land to its maximum capacity, have constantly been thwarted by lack of hands and have made various attempts to introduce foreign labor such as coolies from China. In our own area we have seen that there is a marked strain of negro blood in the coastal valleys, derived from the numerous African slaves introduced by the early Spaniards to work their newly settled land. Agriculture in the valleys in Tacna and Arica has labored under a further disadvantage in the last half-century—the uncertainty of the political future of the two departments.

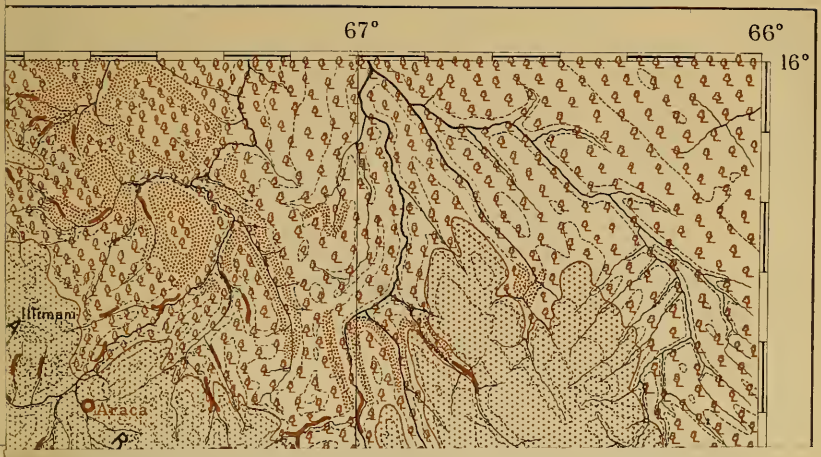
Temperature is always sufficiently high to produce the crops of the coast; but the water comes in its full measure only when the rivers are filled by the summer rains on the Cordillera, so that the seasonal distribution of work in most of the oases is not very different from that in other parts of the country; although the crops in most respects are those characteristic of the Mediterranean, where they depend upon winter rains. But there is another point of similarity which may be mentioned. Many of the coastal farmers own cattle, and it is in the winter—as in the Mediterranean—that these are driven to the valuable if fugitive pastures of the Lomas. The most favored areas, however, such as the lower Tambo valley, can command water at all seasons, and here we find sugar cane in quantity.

These coastal oases serve as the garden of Bolivia and northern Chile, and agriculture is perhaps more varied than elsewhere in the region on account of the production of the numerous Mediterranean crops. Thus there are the olives to pick and press, olive oil to can and export, vines to tend, grapes to pick, and wine

to make—much prized despite a flavor described as "foxy" or "mousey." The Bolivian Indian would almost as soon go without his coca as his universal seasoning of *ají*—known to the world as chili or red pepper; and the coastal valleys annually send several hundred tons of these to the plateau. The Chilean nitrate workers are without local food supplies for man or beast save for the small production in the *canchones* described below. A proportion of the meat can be obtained from the herds above-mentioned. Hay and alfalfa are raised in the oases in quantities for export as dried forage. Likewise vegetables and fruits of all sorts are produced, and the coastal farmers have an ever ready and increasing market for these in the ships which call to provision at Arica.

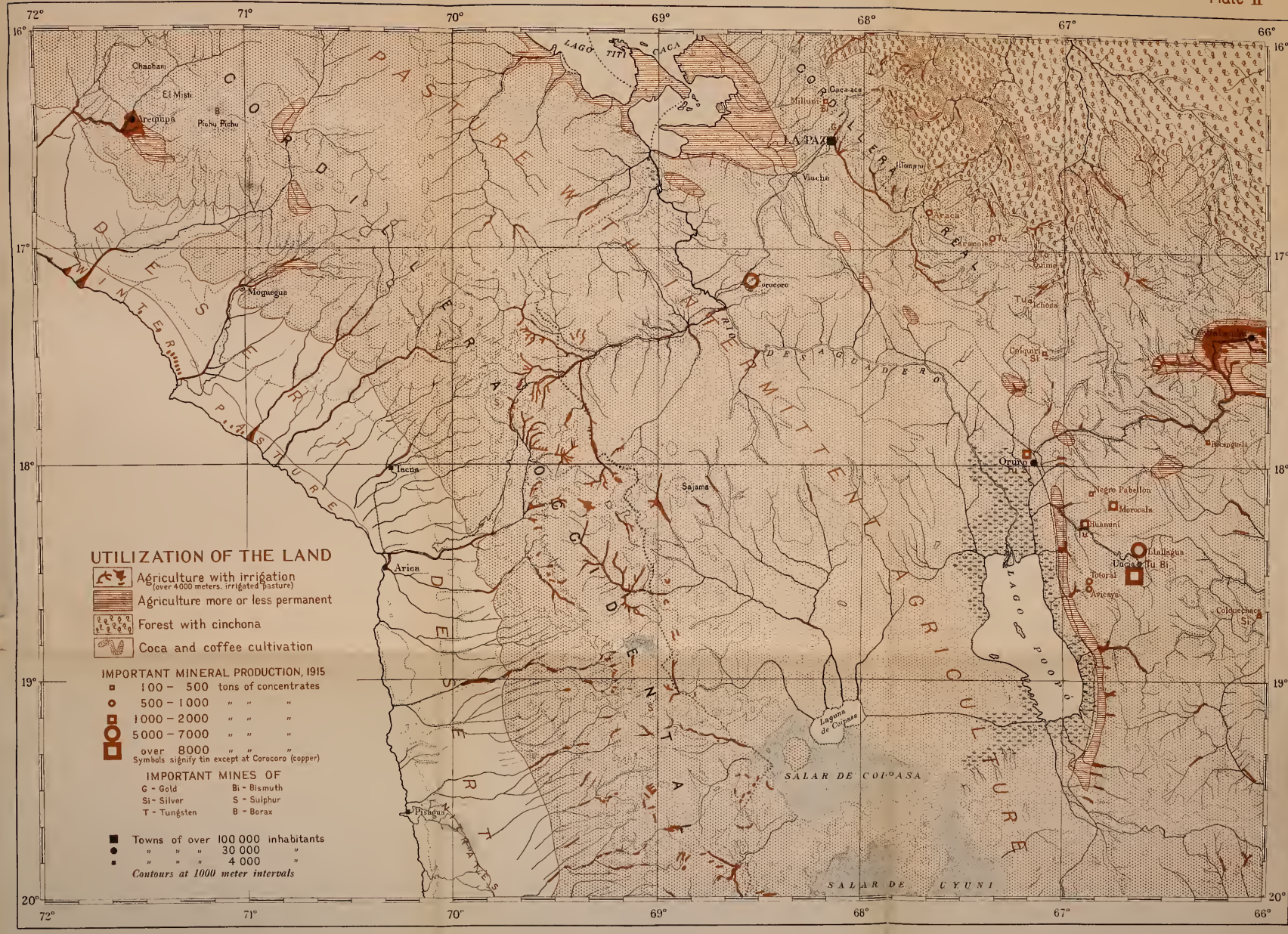
Maize is the chief food staple of the Indians in the valleys themselves, and in point of production it is probably the most important crop. But wheat and barley are also grown for home use, the grain being roasted and ground to meal by hand. The farmers of the valleys are very careful in the use of the precious irrigation water. For instance, where ají is the chief crop the soil is raised about the edges of the beds, and wheat or barley is sown on the embankments in clumps about a meter apart. This holds the bank together and helps to keep the water on the ají beds. The cold coastal water is probably responsible for the fact that the southern limit of true tropical products lies in our area and not farther south. Cotton is not cultivated with success south of the oasis of Ica in Peru, and no Egyptian cotton at all is raised in our area. Sugar cane, however, thrives where the water is sufficient, and a large part of the alluvial Tambo valley and delta is occupied by cane plantations. The contrast of arid desert slopes and wide verdant flats is here most striking. The eye is further attracted by the lines of poplar trees along the ditches between the fields. These trees, however, can have no good effect upon the yield of the sun-loving cane. The plants need two years to come to maturity and may then be cut twice where the soil is shallow and from three to five times on the deeper alluvium nearer the mouth, the harvest taking place

Plate II



LA PAZ

Plate II


72°
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LAGO TITICACA
LA PAZ
Coca-aca
Millumi
Illimani
Viacha
Yaca
Caracoles
Colmi
Tua
Ichosa
Corocoro
Calquni
Oruro
Sajama
Negro Pabellon
Morocala
Illiamni
Tu
Ullagua
Uncia
Tu Bi
Totoral
Avicaya
Colquechaca
Lagoa Poopó
Laguna de Coipasa
SALAR DE COIPASA
SALAR DE UYUNI
Arequipa
Chachani
El Misti
Pichu Pichu
Mollendo
Mejillones
Mogneguа
Iacna
Arica
Pisagua
COSTA DESERTA
DESIERTO DE ATACAMA
PASTURE WITH INTERMITTENT AGRICULTURE
PASTURE
DESIERTO DE ATACAMA
COSTA DESERTA
COSTA DESERTA
COSTA DESERT

between August and December. The bulk of the cane in these valleys is devoted to the production of alcohol, which, as we have seen, is in great demand throughout the country and especially on the plateau. Sugar extraction, when carried out locally, is primitive, there being no separation of the crystalline and colloidal materials. The solidified mass (*chancaca*) is exported in cakes.

Where the soil is salt but yet is not far from the water table, as is the case in parts of the Pampa del Tamarugal, a remarkable form of cultivation has long been carried on. The superficial saline layer is removed and built up in long banks known as *canchones*, set at right angles to each other. The intervening spaces are now fit for cultivation, the hollows being sufficiently deep to allow roots to penetrate to the ground water, or perhaps to allow the water to reach the roots by capillarity, while the banks serve as a protection against wind and reduce evaporation. Vegetables or wheat and even trees such as a mesquite (*Prosopis dulcis*) are sown in separate holes. As they sprout the plants are surrounded with good earth, and while they are still small they are protected by individual shelters.

Mining

We have so far omitted to deal with an important element in the life of the region and especially of the Puna. Throughout the century following the Conquest every Spaniard was a prospector, and individuals obtained valuable mining concessions subject to the payment of a fifth to the royal treasury. For the working of the mines the government established the system of forced labor (*repartimientos* and *mitas*) by which concessionaries were allowed to impress the Indian laborers, many of whom were already skilled in mining. The great initial prosperity of mining came to an end when silver fell in value and also became more difficult to extract. But the increasing value of tin in the nineteenth century led to a great recrudescence of the industry helped by foreign capital. The mines today are nearly all in the hands of foreign companies or of a few Bolivian individuals.

While the foreign companies are mainly European and North American, there is an important and growing Chilean interest in Bolivian mines, especially at Corocoro and Llallagua. The population about a mine consists, as a rule, of a small number of white engineers, a larger number of cholo overseers, who live with their families, and the much larger number of Indian miners. The latter, as pointed out, are free Indians drawn from the old communities. Some of them have settled in the district, especially where the mines are long established; and these have with them their wives and families who often cultivate a little land near the mine, generally with poor results, since the mines are mostly situated at high altitudes. But the great bulk of the miners are transitory, the Indians engaging voluntarily in many cases but leaving their community only for a period of months. Where located far from centers of population it is so difficult for mine owners to obtain the necessary hands that they sometimes adopt methods which are far from being above criticism. The revels of the fiestas are favorite occasions for the visits of the cholo mine agents to the communities. Liquor is flowing freely, and it is easier to persuade the Indian to agree to serve then than at other times. A large advance of money—promptly spent on drink—clinches the bargain, and the Indian when sober becomes the slave of the mine, to remain so until his debt is paid off.

Of the total population of the province of Tarapacá, given in the census of 1907 as 110,000, 23,000 were Peruvians, and 12,000 were Bolivians. A large proportion of these were undoubtedly workers in the nitrate fields, so that we have to note an important movement of Indians from the plateaus to the coast for mining purposes. Many of these are engaged by contract; and, taking their families with them, they remain for long periods. Others come down with caravans and take service for a few months before returning to their homes.

Movement

Figure 38 consists of three sketch maps, showing approximately the relative importance of traffic routes in the area at different

periods, and a fourth map on which are indicated the dates of construction of the various railways. On maps A, C, and D the thickness of the lines mark in a general manner a grading of the amount of traffic on the routes; and such lines are to be compared only with other lines on the same map. On map A, illustrating conditions in the colonial period, all of the lines, of course, indicate pack roads. On maps C and D only the most important of these and of the coach roads are shown, the majority of them being feeders of the railways.

In prehistoric times prior to the rise of the Inca dynasty it would appear that Tiahuanaco was the kernel of the whole puna region of South America. It was a large city whose inhabitants could not have been fed by the immediate neighborhood, evidently a center of government supported by tribute from distant provinces, like Rome at the height of its splendor. With the decay of Tiahuanaco and the rise of the Inca capital at Cuzco the center of gravity in the Puna shifted north of our area, and arteries of communication developed, leading from the heart of empire to the outer marches which lay well beyond the La Paz area. Throughout the Inca period, then, the maximum movement of people must have been along roads following the north-south trend of the Puna, with branches to the coast lands by Arequipa, to the Yungas by La Paz, and to the eastern Andes by Cochabamba.

The Spanish Viceroyalty of Peru was governed from Lima, and the same roads which served the Incas became the means of interchange between the various mountain provinces of the new state. But the Spaniards sailed upon the sea and so developed ports, Quilca, at the mouth of the Río Vitor, to serve Arequipa; Ica, by which some of the coastal valleys were tapped; and Arica, as the main point of access to the Altiplano. Moreover the Spaniards occupied Chile, far beyond the domain of the Inca; and, since it often took twelve months to reach the Chilean settlements against adverse winds and currents, they developed the desert road along the foot of the Cordillera. The great mining activity of the early Spaniards caused them to seek an outlet

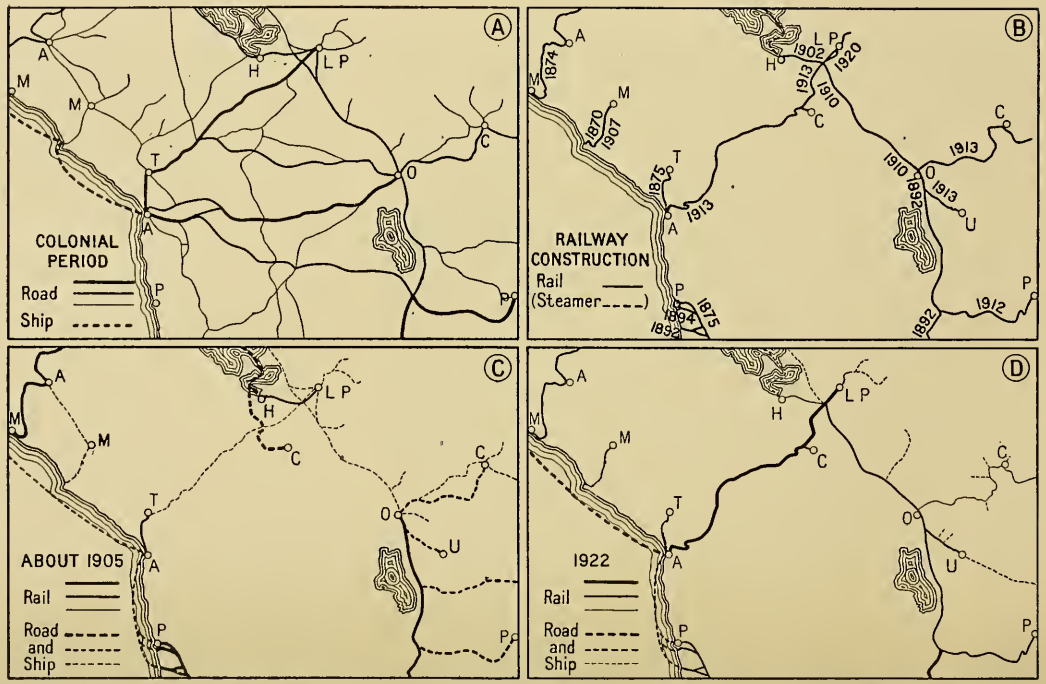

FIG. 38—Sketch maps illustrating the relative importance of routes at three periods (A, C, and D), and railway construction, 1870–1922 (B).

for their minerals. Arica, the first accessible port north of the Atacama desert, was the obvious goal; and so there developed a great fan-shaped concentration on this port reaching out to the eastern Andes as far south as Potosí. A considerable proportion of the Potosí silver, however, went southwestward to the port of Cobija.

Such were the main currents of movement up to the time of railroad development; and, since the Indian population is not yet given to railway travel, it may be said that the old roads still have great though somewhat lessened importance. Let us examine in more detail the location of these.

Of the longitudinal routes by far the most important is that leading from Puno in Peru, following the west shore of Titicaca, crossing the Desaguadero by a bridge at its source, and thence leading by Viacha, with a branch to La Paz, along the foot of the eastern ridges and Cordillera. At Paria this road divides, one branch continuing southwards by Oruro and the other leading over the hills to Cochabamba. The southward road splits at Río Mulato, as does the modern railway, its branches leading respectively to Potosí and Sucre and to the Argentine border via Uyuni and Tupiza, both beyond our limit.

From Paria to Cochabamba the easier route now followed by the railway provided for normal traffic while a hill road, passing through Tapacari, comes into more general use during the wet weather when the Arque River causes obstruction on the lower road. Beyond Cochabamba the main road passes eastwards into the basin of Cliza and so, by a gradual descent, to Santa Cruz at the eastern foot of the Andes.

Prior to railroad construction the mineral output from the southeastern part of our area found its way to Arica by a caravan trail which strikes west-southwest from Oruro across the plateau and then, after passing through the pastures about the upper Lauca River, descends either by the Lluta or Azapa valleys to the coast. Of the trans-Cordillera roads, however, the one which has been of most constant importance is that which leads from the town of Tacna northeastward and succeeds in maintaining

an almost straight course to La Paz, striking the upper Mauri River and then keeping to the higher ground north of it, and crossing the Desaguadero at Nazacara. The direct road from Arequipa to the Puna finds fairly easy gradients by passing eastward over the Pampa de Salinas and then northeastward over the high plateaus to Puno on Titicaca. La Paz has always been the main starting point for the Bolivian Yungas. The bulk of the through traffic which moves along the eastern shore of Titicaca is going to or from Sorata, the collecting point in the northern Yungas, and an even more important traffic is maintained on the road over the pass at Rinconada and thence down either to Coroico or Chulumani. An observer has counted 1,600 laden animals making their way up from Yungas on this road in one day, and that not the chief market day of La Paz.

The traffic from Arequipa to the coast formerly went down the Vitor valley to its mouth where Quilca was long maintained as the port of Arequipa. But since the railroad was built Mollendo has become the port, and the Vitor road has lost in importance. The position of the desert road, followed during the conquest of Chile by Almagro on his return and by Valdivia on his outward march, is determined by the points at which limited supplies of food, water, and fodder can be obtained. It therefore passes over the piedmont from oasis to oasis, keeping as near to the edge of the desert as is possible without climbing far on the slopes of the mountains. This route is said to have been in constant use by the Spaniards up to the time when the ocean sailing track—as opposed to the coastwise course—was discovered early in the eighteenth century. These were the chief avenues of movement up to the period of railroad construction. Other routes are either of purely local importance or serve as tributaries to these main arteries.

The term "road" has been used in the above description as well as in the legend printed on the La Paz sheet. It cannot be too strongly emphasized, however, that roads in this area are not like those of more progressive parts of the world. So far as has been ascertained, there is but one metalled road within the

sheet area, and that has been built by a mining company to bring their ores from the Caracoles and other mines in the Quimsa Cruz Cordillera over the Abra de Tres Cruces and down to the railway at Eucalyptus. Elsewhere on the sheet the symbol for a "coach road" where shown implies that passenger or mail coaches and other wheeled vehicles, such as occasional automobiles, use them or have used them in recent years. It does not imply that the surface is maintained or that streams are all bridged; but the roads are kept in repair and graded in many places—especially where cut along a mountain slope to avoid the washouts which damage roads at lower levels. On the other hand, the symbol used for "pack roads, trails, and paths" includes routes of all qualities, from the trail linking villages on the Altiplano which are often difficult to distinguish from the pampa on either side to the main pack roads of the mountains, such as that from La Paz to Chulumani, upon which an immense amount of labor and money has been spent in cutting, embanking, paving, and bridging. In Bolivia it is such *caminos de herradura* that are the chief concern of the Department of Public Works.

Railways

The Revolution led to increased interest in this region on the part of foreigners, and it is only natural that the first railway construction took place in the most accessible part—the coast lands. The line from Moquegua to its port of Ilo was opened in 1873 to serve for the export of the products of the Moquegua valley—largely wine and brandy. This railroad, however, was destroyed in the War of the Pacific and was not rebuilt until 1907. Another and more important result of the introduction of foreign capital was the development of the nitrate industry with the foundation of the port of Pisagua (see Fig. 1) and construction of a railway to it in 1875, to be followed in the early nineties by the opening of lines to the newer ports of Caleta Buena and Caleta Junín. An essential feature of the political and strategic organization of Chile has been the building of the longitudinal railroad throughout its great length north of 40° S.

Only the final section of this remains to be built, the plan being to connect Zapiga on the Pisagua line with Arica. The Peruvians, encouraged by the success of the Moquegua railway, and to meet a similar need, constructed the line from Tacna to Arica; and this was long thought of as the first section of a railway to Bolivia. But the continuation was never undertaken.

The greatest feat in opening up the Central Andes—the building of railways up to the high plateaus—still remains to be treated; and the great importance of topography in this elevated region is brought home to us in a remarkable manner when we consider the facts of route selection, railway competition, and movement of commodities in the last half-century. Primarily of course railways have penetrated to the heart of the Cordilleras in order to tap the ores they produce and so to promote mining; and we may note with advantage the swift changes which have taken place in the direction of this export, as the various railways in turn crept up to the plateau and pushed their heads nearer to the different mining centers.

The Peruvian Corporation was first in the field with its line from Mollendo along the shore and up over the desert pampa to Arequipa and thence by severe gradients to the plateau and Lake Titicaca, which it reaches at Puno. This line was opened in 1874. In addition to serving Arequipa and tapping the agricultural and pastoral resources of a wide area of Peru, it opened a new route for export of Bolivian ores; for after some delay a steamer service was established on Lake Titicaca from Puno to Huaqui, which had the effect of diverting much of the ore from the llama caravans on the Tacna road. In particular, the new route took the entire production of the Corocoro copper mines and greatly stimulated production there. This is all the more striking in that the distance by the new route was so much greater, while the ore had to be handled six times between mine and ocean steamer, viz.: loaded on mule cart or llama back; carried to the Desaguadero; shipped in shallow-draft barges on that river; transshipped to the lake steamer at Huaqui (see Fig. 39); loaded on the train at Puno; and finally at Mollendo,

FIG. 39—The port of Huaqui looking east from Lake Titicaca. Huaqui is the terminus of the railway from La Paz and the port of embarkation for Puno, the terminus of the Mollendo railway. In the background is the north face of the Cerro de Quimsachata. a typical ridge of the Altiplano, exhibiting mature slopes.

where steamers cannot come alongside, first put into lighters and thence hoisted into the steamer hold in the roadstead. In 1902 La Paz was linked to this sytem by the building of a railway to Huaqui.

The port of Antofagasta is over 400 kilometers south of our limit of 20 degrees. From this port a narrow-gauge railroad was constructed in a northeasterly direction to tap the rich copper mines of northern Chile and pushed up over the plateau, reaching Oruro in 1892 and thus at once draining the bulk of the mineral districts of Bolivia southwards to Antofagasta. In 1912 the facility of export in this direction was further increased by opening of the line from Río Mulato to Potosí; but it is worthy of note that even after the Antofagasta railroad had reached Oruro a constant stream of freight from the plateau as far south as that city continued for many years to be moved by caravan to Arica, and the extension of the Antofagasta line from Oruro up to Viacha in 1909 did not completely drain the produce of this region to the southern port.

The last stage in this contest for the traffic of the plateau was initiated in 1913 by the completion of the Arica-La Paz railroad. This line was not made an extension of the Arica-Tacna railway but was constructed in the Lluta basin, reaching the summit near Lago Blanco, continuing down the Mauri River, and taking an easy course over the plateau which brought it within a few miles of Corocoro. About the same time the railway from Oruro to Cochabamba by way of the Arque valley was finished. In consequence of these recent developments the freight routes at the present time are again undergoing readjustment but probably for the last time. To help in visualizing the changes in the relative importance of routes, three sketch maps are given (Fig. 38) representing conditions in different periods.

As far as the country south of La Paz is concerned, competition is now entirely between the ports of Arica and Antofagasta, Mollendo having dropped behind, presumably on account of the transshipment difficulties. In 1916 the relative volume of exportation by the three ports in metric tons was as

follows: Antofagasta 80,977, Arica 43,563, Mollendo 4,957. It seems clear that the figure for Arica does not represent the position which that port and its railway will hold in the future. The new line suffered greatly for the first two years from the lack of rolling stock, and it is unlikely that by 1916 complete adjustment had taken place. We may usefully compare certain features of the three railway routes to La Paz.

Port	Length in Kilometers	Summit in the Cordillera Occidental	Time from La Paz	Time to La Paz
Arica . . .	439	4,257 meters	17 hrs.	25 hrs.
Antofagasta.	1,157	3,956 meters	48 hrs.	53 hrs.
Mollendo . .	850	4,470 meters	35 hrs.	45 hrs.

Considering distances from the ports along the various routes we may note that a point which is halfway between Arica and Antofagasta on the now continuous railway linking the ports by way of Viacha and Oruro would form a natural divide for freight north bound and south bound. This point is just south of Challapata, east of Lake Poopó, and it would appear that under present conditions the Viacha-Arica railway should form the avenue for all freight derived from or destined for all the plateau area represented on the La Paz sheet save a small strip in the south. Furthermore, a railway project which has been much favored by mine owners south of Oruro is the construction of a line from Charaña, the frontier station on the Arica railroad, directly to Oruro, keeping to the south of the middle Desaguadero. There is no geographical reason for thus doubling the line in the Mauri valley, and great economy would evidently be effected by making a junction in the neighborhood of the Mauri viaduct near Viscachani. But, whatever be the detail of this railway construction, it remains true that, if it be carried out, the imaginary line which we term the "freight divide"

would be moved southward beyond Río Mulato. By this the Arica railroad would be the gainer, having tapped the heavy traffic from the Potosí district.

Of the railways so far mentioned probably the only one that serves agricultural interests to any great extent is that from Oruro to Cochabamba. This line serves as distributor of produce emanating not only from the Cochabamba basin itself but also from the southern Yungas and the warm valleys drained eastwards to the Río Grande. There is a project to extend the existing railway, on the one hand, into the former district and so to reach the head of navigation on the Chaparé, a tributary of the Mamoré, and, on the other, to Santa Cruz and so on to the Paraná River at Puerto Suarez. In the latter direction there is already a short electric road as far as Punata in the rich agricultural basin of Cliza.

East of La Paz lies the best-developed section of the Yungas. And we have seen that traffic up and down these valleys is heavy. It would seem, then, that the Bolivian government is fully justified in the construction of the mountain railroad up the Chuquiaguillo valley and down the Unduavi. This railway will undoubtedly be prolonged to Chulumani, but it remains to be seen whether it will ever connect with navigation on the Beni River. A railway route has been surveyed from Coroico to Rurrenabaque, some 200 kilometers to the north, so that in time the traffic link between La Paz and the Amazon may be forged in that direction. In discussing railroads in this region we have not had to make reference to projects in any great degree. The riches of the mines have made realities of most of the projects here. Development of additional mines will probably mean new branch lines or at least new automobile roads, but of trunk lines there would seem to be room for no more, unless it be the linking of the Peruvian and Bolivian systems by a line along the western shore of Titicaca from Puno to Huaqui.[16]

[16] For related discussions see Isaiah Bowman: Trade Routes in the Economic Geography of Bolivia, *Bull. Amer. Geogr. Soc.*, Vol. 42, 1910, pp. 22–37, 90–104, and 180–192; and *idem:* Regional Population Groups of Atacama, *ibid.*, Vol. 41 1909, pp. 142–154 and 193–211.

Leading Cities and Centers

The La Paz sheet includes five cities and towns which demand special attention from their importance, not only to this particular area but to the Central Andes as a whole. These are La Paz, Arequipa, Cochabamba, Oruro, and Arica.

We have seen how the early Spanish settlers gradually pushed their dominion southwards from Peru towards the pampas of Argentina, and it has already been noted that it was found convenient to establish an important post about halfway between Cuzco and Potosí. This post, which has become the city of La Paz, was founded in 1548 under the name, El Pueblo Nuevo (The New Town). Had the post been fixed actually upon the route, it would have stood in the neighborhood of the present Viacha, that is on the bare plateau itself; and it is most unlikely that it would have developed into the greatest city in the Central Andes. La Paz holds this position in virtue of its being the center of government in Bolivia; and the government is centered there and not at Sucre, the legal capital, because of the nodal position required by a metropolis.[17] The city enjoys a climate which, while it is not ideal, is yet far more supportable than that of Viacha, and its disadvantage of lying nearly 20 miles off the main road on the plateau and 600 meters below its level is now met by two railroads which descend to the city itself. Thus La Paz is now in a position to draw almost the maximum advantage from its nodality. This advantage will be complete if and when the Yungas railway has been extended to the head of navigation on the Beni River. The population of Bolivia is crowded—relatively—in this western section of the country. From south, from west, and from both shores of Titicaca routes converge here. Moreover, La Paz is the starting point of the easiest road from the plateau to the Yungas and ultimately to the Amazonian plains. Successful government in the less accessible parts of South America is largely a matter of communications. Where these are difficult the government is ill-informed of happenings

[17] It is in virtue of this that La Paz is indicated on the map by the symbol for capital city.

in its more remote territories, and it is in these that revolutions tend to break out. A President at Sucre would be hopelessly out of touch with affairs in the Yungas, and that city stands on the very edge of the mining zone and beyond the well-peopled region of Bolivia. La Paz as the center of government and of business has grown very rapidly in recent years. Its population has increased from 60,000 in 1900 to 78,000 in 1909 and 101,000 (estimated) in 1920. With its public buildings, churches, plazas, markets, busy thoroughfares, the city really looks like a capital. The foreign visitor to La Paz carries a lifelong memory of its wonderful setting, unique among capitals. From the Alto the

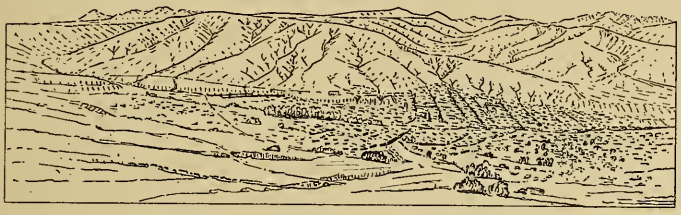

FIG. 40—The site of the city of La Paz, from the southwest. In the distance are peaks of the Cordillera Real with Caca-Aca and Huaina Potosí (left); the smooth upper surface in the middle distance is an extension of the Altiplano; the glaciated valleys of the upper La Paz (left) and Chuquiaguillo (center) are incised below this surface. The city is partly on a terrace and partly on the lowest slopes of the main valley. Drawn from a photograph.

city is seen to nestle far below, not quite at the head of the deep trench in which it lies but near the spot where the torrential Chuquiaguillo River tumbles down to join the La Paz River, which threads the city itself. The steep valley sides contrast with the smooth upper edges of spurs and plateau, and these remnants of an ancient topography rise gently as they recede, till they lap against the rugged walls of the Cordillera with its crown of snow and ice. The latter is visible in more than half its extent—from Caca Aca on the left to Illimani on the right. Towards the latter the middle distance is occupied by a labyrinth of spurs and narrow valleys cut in the weakest of rocks. Light and shade bring out the valley sculpture in its finest tracery of

earth pillars and dendritic scrolls. Perhaps aesthetic appreciation of this magnificent situation as well as the city's history contributed, when the New Town was rechristened under the dignified title: Nuestra Señora de la Paz, which name, after independence had been won, was changed to its present form, La Paz de Ayacucho.

Arequipa is the metropolis of southern Peru and the second city in that country. Throughout its long history it has derived its relative importance mainly from three facts: that it possesses a considerable stretch of irrigable land on a gently sloping pampa; that in all of southern Peru this is the only extensive agricultural area intermediate in altitude—Arequipa is at 2,295 meters—between the hot coast lands and the Puna; and, lastly, that it is situated on a relatively easy route between a port—Quilca—and the thickly peopled Puna north and west of Lake Titicaca. Arequipa is therefore admirably placed as a center for exchange of the products of Puna and coast.

The city stands on the open pampa on the eastern bank of the Río Chili which flows in a deep quebrada. It is a well built city of stone laid out in rectangular blocks, and slopes gently from north to south. Above the city stands the astronomical observatory maintained by Harvard University. From the scenic standpoint it is the background which makes Arequipa. Seen from the southwest the city appears to be crowned by the perfect cone of El Misti with its peak, snow-capped for most of the year, 3,500 meters above the town and 18 kilometers distant. To left and right stand respectively the triple peaks of Chachani and the rugged ridges of Pichu Pichu, the first separated from El Misti by the profound canyon of the Chili and the second standing out from the flat horizon of the Pampa de Salinas. The census of 1876 credited Arequipa and its suburb of Miraflores with a population of 29,000, while the number today is not much less than 40,000, and it would appear that the greatest increase took place soon after railway communication was opened. One result of this was the development of industry, such as cotton and grain mills. Arequipa, like Cuzco, is noted as a hotbed of revolution.

Both are centers of outlying departments, and the lack of direct railway communication with the capital is doubtless a contributory cause.

In 1574 the Spaniards, appreciating the kindly climate and good soil of the "wet plain" (*khocha pampa*) of the Rocha, founded the Villa de Oropeza there. The city remains under the Indian name as Cochabamba. Its site in the enclosed basin which it dominates is determined by a rocky prong of the southern hill. which causes a constriction in the pampa threaded by the Rocha. Just below the city that river receives the tributary which drains the wide basin of Cliza to the southeast. Cochabamba is the meeting point of the ways leading, on the one hand, through this basin and spreading fan-wise over wide tracts of the eastern Andes and, on the other hand, up the Rocha valley and over to the Yungas and the Río Chaparé.

The impression left in the mind of the visitor to Cochabamba is of a pleasant, hospitable city with many trees and animated by the life of an important market brimming with the fruits of the soil. As such it has an importance much greater than is indicated by the number of its permanent inhabitants. These were estimated in 1918 at 31,000; the census of 1900 giving a total of 22,000. The pampa presents a smiling aspect with its well-grown crops and innumerable fruit trees. The rushing Rocha forms an alluring foreground in this arid land, and the bold scarp of the Tunari, while it does not match the background of La Paz, yet fits the landscape, and without the presence of this protecting range the fertile basin is unthinkable; indeed it would not exist. Cochabamba is the most Spanish of all the cities in our area. Its climate and the fertility of its soil caused the early settlers to make it their home, and today the customs of old Spain prevail to a marked degree.

A greater contrast in aspect and life could scarcely be found in the region than that between Cochabamba and Oruro. The convergence of the road from the former with the piedmont road of the Altiplano would naturally be an important place, especially as it is halfway between La Paz and Potosí. But its location

would be that of Paria, close to the hills. But Oruro is the real junction of roads as it is of railways. The cause for the momentum acquired by this city is the small group of hills which raise their bald heads from a still more barren pampa, which separates them by ten kilometers from the escarpment of the eastern plateaus. To this inhospitable spot the early Spaniards were attracted by the silver lodes of the hills, and they made their settlement as best they could on the east side of the group where they obtained at least some shelter from the cold and dust-laden winds which sweep the Altiplano in the winter. The city was styled the Villa de San Felipe de Austria, but its aboriginal name Uru Uru—probably derived from the presence of a group of Uru Indians—has survived in the present form. But Oruro has been little better than a mining camp throughout its long history. It is in no way favored by nature; at no season is its climate pleasant, scarcely a tree is to be found in or about the city, and even the inadequate water supply has to be piped across the pampa from the Cordillera. The drab aspect of the blocks of low adobe houses is only heightened by the artificial pretentiousness of the ornate government buildings in the main plaza.

Oruro was founded as a mining center in 1568, and such feverish activity reigned in the following century that by 1678 there were some 38,000 Spaniards living there, and the Indian population must have been at least as great, making a total of 76,000. The extent to which silver mining had fallen off by 1859 is reflected in the population of that date—7,980. From then onwards the Cerro de Oruro has again been known as a great tin-mining center. By 1900 its population had grown to 15,900, and, as this industry received a great impetus from the advent of the railroad, it is not surprising that the city in 1920 numbered about 31,000 inhabitants.

Arica, little more than a village with its 5,000 inhabitants, merits special treatment here because of its future rather than on account of its past. Yet even in the sixteenth and seventeenth centuries it would have maintained a greater population, had it not been for a well-grounded fear of the English raiders, of whom

Sir Francis Drake was the first and best known. This, as well as the frequency of earthquakes, discouraged settlement in the little port. Arica is of great importance strategically and commercially. At the present time it is occupied by the strongest naval power in western South America, Chile, which holds the nitrate fields. Early in the War of the Pacific the capture of Arica was effected by Chile, and it was a vital stroke. So long as attack by neighbors is likely the holder of the nitrate fields must be able to dominate Arica and its relatively sheltered harbor from the sea. We have seen that as the terminus of the La Paz railway the port of Arica is destined to deal with an ever-increasing traffic with Bolivia. Without a doubt it must soon become Bolivia's first port. The town with its limited resources of water and food will probably never grow to be a large city, but with the future development of warehouses and possibly of smelters a considerable increase in its population is to be expected, and its importance to the Central Andes will always be greater than its size would imply.

The absolute dependence of the Andean Indians upon the produce of the soil accounts for the deep-seated desire on their part to propitiate the natural elements, or rather the spirits which they conceive to control them. Their religion, while nominally that of the Roman Catholic Church, at bottom consists in the worship of such spirits, and, while the celebrations of the Church are observed, these often coincide with the time-honored festivals of the pre-Christian period. Thus the celebration of Corpus Christi about the end of May coincides with the primitive festival marking the conclusion of chuño making. The ancient festivals, or holidays, were combined with periodic fairs, and so today there is a general agreement of the dates of the important Christian celebrations with the holding of annual fairs in one place or another. There is however, a general absence of fairs in the rainy season, for there is much work to be done in the fields, and roads are then difficult to traverse.

These annual fairs are a feature in the life of all large villages which are centers of districts; but there are two places in our

area whose fame spreads beyond these limits. Each of them draws thousands of people from far and wide for one week in the year. These are Copacabana, on the western side of the peninsula of that name in Titicaca, and Huari, on the eastern side of Lake Poopó. Copacabana is the reputed birthplace of the Children of the Sun, and the wise ecclesiastics of the Conquest in their effort to convert the natives erected on this most sacred spot of the Indians the shrine of Our Lady of Copacabana. There is a weekly market at this place—as in hundreds of others—but market day here is Sunday, so that trading may be combined with religion. Moreover, it is the idea of annual pilgrimage which renders the Copacabana fair so important when it is held. Were it not for its religious importance Copacabana would probably not have been chosen as the location of a leading fair.

Huari is a small village situated on the narrow piedmont strip between Lake Poopó and the eastern Andes. For fifty-one weeks it is a much less important place than Challapata, ten kilometers north of it. But in the week following Holy Week the village may contain ten thousand people, and during that time a busy trade is carried on. From its location Huari is a convenient point for such a concourse. By the road from Sucre which reaches the piedmont at Challapata come the farmers of the warm valleys in the Rio Grande basin as far as Santa Cruz bringing their grain, sugar, wine, and fruit. By the roads from the north come the traders of Yungas with their coca and other tropical produce. By the southern road come grain from Tupiza and chinchilla skins from Lipez, and from distant Argentina come droves of fattened cattle, mules, and donkeys for sale. The Puna itself sends its products in quantities—woolen fabrics, wrought silver, chuño, etc. Since the resources of Huari are limited, elaborate preparations have to be made. The fair is administered by the municipality of Challapata for which a contractor organizes temporary shops, corrals, etc., paying a high price for the privilege but deriving good profit from his week's labor.[18]

[18] For details see Gladys M. Wrigley, (145).

Geography and Political Organization

Just as the physical characters of the land have largely determined the course of man's occupation of it and his distribution upon it, so also the political organization of the country has always been guided at least in part by geographical considerations. This is best seen in the positions and movements of political boundary lines. In the earlier periods of their history—and prehistory—territories of clans, races, and empires were probably separated not by boundary lines but by frontier zones which were contested incessantly by neighboring tribes. Archeology has revealed the existence of a prehistoric empire, of whose culture the chief feature is megalithic structures. This empire is believed to have extended over the high Andes from 12° S. northwards to 5° S. and down to the coast between 5° and 15°. The later Inca empire from its nucleus at Cuzco was extended gradually in both directions along the Andes, until at its apogee, between 1488 and 1530 A. D., it included all of the ancient megalithic empire and more, reaching on coast and mountains to the equator and along the Pacific coast to the site of Valparaiso. These great empires, then, furnish a wonderful example of political units extending throughout entire natural regions—the Puna on the mountains and the desert on the coast. All the high lands and dry lands came under their sway, but never the wet and forest lands. The Inca empire in fact corresponded in marked degree with the range of the condor—the animal king of the Andes.[19]

The frontier zone with the forest tribes was the eastern slopes of the Andes. Where this frontier was regarded as vulnerable, in parts of Peru and in the plateaus east of our area for instance, it was defended by forts dominating the valleys. But apparently the Cordillera Real was considered as a sufficiently strong natural barrier, for no undoubted remains of fortifications have been found there. Similarly throughout the whole of the Spanish

[19] The maps in the papers of Philip A. Means, (111), and Erland Nordenskiöld, (128) may be consulted.

period, while various expeditions went down into the forest, mostly in search of gold, many never returned, and the forested lowlands were never occupied. They were organized as "military governments."

We have seen that Lake Titicaca from an early period has divided Quichuas from Aymarás; and ever since the Spanish Conquest a political boundary has existed, running from the Cordillera Occidental in the neighborhood of the Arica-La Paz route in a general northeasterly direction to the Cordillera Real. This was first the limit of the Audiencia de los Reyes (i.e. Lima) and the Audiencia de los Charcas out of which the modern Bolivia has grown. These were two of the five principal divisions of the Viceroyalty of Peru.[20] That the line between the two audiencias was subject to variation from time to time is apparent from the sketch map shown on Figure 41, but it is also clear that Titicaca has always been in a frontier zone traversing the Puna region. The importance of the boundary was increased when in 1777 Alto Perú was transferred to the jurisdiction of the Viceroyalty of La Plata or Buenos Ayres—a change which resulted largely from the development of lines of communication across the eastern Andean plateaus to the Argentine pampas. With the wars of independence in the early nineteenth century this dividing line again acquired increased importance as the international boundary between Peru and Bolivia. The line, from a point on the main divide east of the village of Ancomarca to the point where it meets the Río Desaguadero, is always referred to as the traditional boundary. It is shown on the La Paz sheet in conformity with the most recent available official Bolivian map.[21] This position does not agree with the delimitation contained in the Treaty of 1909,[22] which describes it as starting at Ancomarca, following the summits of Lucilla and Tapara, and thence extend-

[20] The Audiencia y Chancellaria de la Plata, Provincia de los Charcas, commonly known as the Audiencia de Charcas, was established by Philip II in 1559. It came to be known as Alto Perú. It is described by René-Moreno, (133), pp. 201–325.

[21] Mapa del Departamento de La Paz por Eduardo Idiaquez, 1 : 750,000, 1919.

[22] Quoted by Luis S. Crespo, (17).

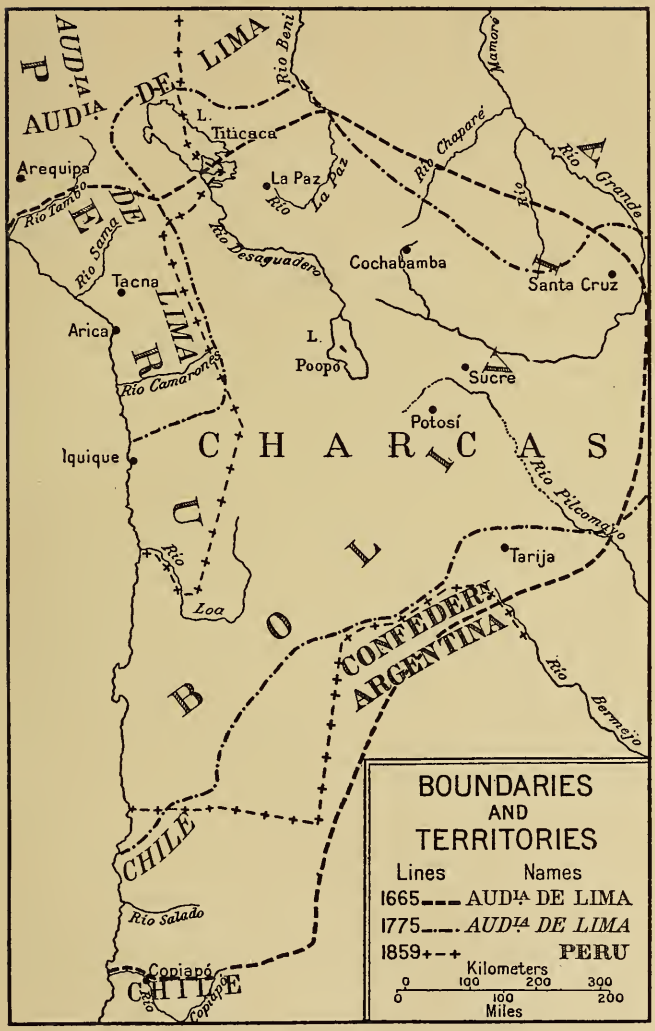

FIG. 41—Sketch map showing boundary changes in the Central Andes. Sources for boundaries are as follows: for 1656, Map by N. Sanson d'Abbeville, Le Pérou etc., Paris, 1656; for 1775, Carte du Pérou by M. Bonne in Atlas moderne, Paris, 1771, and Mapa Geográfico de America meridional by La Cruz Cano y Omedilla, Madrid, 1775; for 1859, Mapa de la República de Bolivia by Ondarza and Mujia, 1859.

ing down to the source of the Yaro, which it follows to the Desaguadero. But it seems likely that the topography in this area has become better known since 1909 and modifications of the line consequently adopted. This section of boundary has not yet been surveyed or demarcated. From the outlet of Lake Titicaca the position of the boundary is accurately known on the ground, but later accurate surveys of the shore line will necessarily modify its position on the map. Where the line traverses the peninsula of Copacabana it follows a very sinuous course, determined by the limits of properties owned by Peruvians and Bolivians.

A more obvious natural frontier is the summit of the Western Cordillera. Soon after the Spanish Conquest it was decided that the whole of the territory within the La Paz sheet should belong to the Viceroyalty of Peru, the northern boundary of Chile being fixed at the Río Copiapó, and by the creation of the Audiencia of Charcas the Altiplano south of Titicaca and the coast lands between the Tambo and the Copiapó were included in this single political unit. Thus for a period the cordillera in our area was not a political boundary. But even at this time the coastal strip south of Arica was virtually disregarded by the Spanish colonists of the plateau, and the barrier shutting off the desert was none the less real. Between 1760 and 1770, however, there was a change in organization of the Kingdom of Peru by which the *partido* of Arequipa had been extended down the coast to the vicinity of Pisagua[23] and the cordillera thus became the boundary between the two Audiencias. Again, after Charcas had been transferred to the Viceroyalty of Buenos Ayres we find an official map[24] showing Peru as extending well beyond our area—to the Río de Loa, thus pushing the coast line of Charcas to the south of that river. Thus the Cordillera Occidental became established as the political boundary which after 1810 separated Peru from Bolivia. In the War of the Pacific, 1879–1883, Bolivia lost to Chile all of her coastal territory and Peru her province of Tarapacá, lying to the south of the Río Camarones, while Chile occupied the

[23] Cf. map by M. Bonne, "Carte du Pérou," in Atlas Moderne, Paris, 1771.
[24] "Plano General del Reyno del Perú," by Dr. Andres Baleato, 1796.

Peruvian provinces of Arica and Tacna. The boundary in the cordillera thenceforward separated Bolivia from Chile and the occupied provinces of Peru. It was delimited in a treaty between Bolivia and Chile in 1904 and a protocol in 1907, and the whole frontier zone was surveyed, and the boundary demarcated, by a mixed commission operating in 1904 and 1905. The entire section of the Bolivian boundary lying north of 20° S. is situated well to the east of the continental divide in the cordillera. This at first sight seems strange and unwise, and we have already noticed some of the disadvantages to Bolivia of this fact. The explanation is simple. The cession by Peru to Chile of her province of Tarapacá and the occupation by Chile of Tacna and Arica meant that the existing eastern limit of Tarapacá became the Chile-Bolivia boundary, while the existing limits of Arica and Tacna for all practical purposes from 1883 till the present time have been regarded as the boundary between Chile and Bolivia. The task of the mixed commission, then, was to establish and demarcate these old provincial limits. Going further back, it may be presumed, in the absence of evidence, that the audiencia of Lima in extending its territory down the coast in the eighteenth century went somewhat beyond the divide in the cordillera, because individual settlers in the coastal oases were interested in utilizing the high pastures of the mountains, while the Spaniards in Charcas who were much farther off, on the east side of the Altiplano, were not interested in such developments. The boundary claimed by Chile as corresponding to the limits of the old Peruvian provinces does not seem to have been seriously contested by Chile.

With the conclusion of the War of the Pacific, Bolivia became an inland state, while Peru shrank northward on the coast. The boundary between her territory and that of Chile remains unsettled on account of the dispute over Tacna and Arica. This subject is treated in some detail in Appendix B, and I shall only refer here to the nature of the various boundaries which are affected. In the event of the old provinces being returned to Peru the international boundary will be the northern limit of Tara-

pacá. This line, which is marked on the La Paz sheet, lies in the Río Camarones and its more northerly head stream, the Ajatama, as far as a point west of Tarahuire, whence it runs northeast to the Cerro de Puquintica where it meets the Bolivian boundary. In the event of the occupied territory becoming Chilean the international line will presumably be the Río Sama from its mouth to a point above Caribaya. Beyond this its position would be in doubt. Chile occupies all the land up to the boundary shown on the La Paz sheet which follows the Río Cano to its source and thence crossing the upper Mauri runs eastward to the Bolivian boundary at the Cerro Chipe. The Peace Treaty of 1883 allowed Chile to occupy the provinces of Tacna and Arica "bounded on the north by the Río Sama from its source in the cordilleras which limit Bolivia to its mouth." Peruvians hold that Chile went beyond her rights in selecting the westernmost branch of the Sama for her boundary and claim that the district of Tarata, which corresponds roughly to the basin of the Sama within the cordillera, was wrongfully occupied by Chile.

The line dividing two Chilean departments of Tacna and Arica, shown on the La Paz sheet on the synoptical index only, follows the Quebrada de Caunani, crosses the Arica-La Paz railway north of the station of Puquios, and passes by the Cerro de Tarapacá to the Bolivian boundary on the Nevados de Payachata. If this line were to be adopted as the international boundary, by way of compromise, two railways would be cut by it—the Arica-La Paz and that from Tacna to Arica.

It is noteworthy that all the boundaries mentioned on the Pacific slope follow rivers which feed oases in the desert; and the inconvenience that must result from making a frontier out of a river, of which every drop is required for irrigation, must be apparent.

APPENDIX A

THE SOCIAL AND RELIGIOUS ORGANIZATION OF THE PLATEAU INDIANS

By George M. McBride

From very early times the social organization of the Indians was based upon the clan, as among other American aborigines; and the kinship group, which was the unit of their society, was the *ayllu*. It would seem that after the establishment of the Indians as a sedentary agricultural people, the ayllu had become an agrarian unit as well as a social bond, since the land was held collectively by this body and was administered by the head man of the community. Each year the land was distributed anew; one portion being set aside to be cultivated by the people for religious purposes and for the sustenance of those engaged in this, another portion—usually the best—for the head chief (in later times the Inca) and his attendants, the remaining land being distributed among the heads of individual families. The land, however, was not alienable. All parts of it continued to belong to the ayllu, even that assigned to the rulers and the priests. These latter received only the fruits of the land, the people in this way (in cultivating these portions for their superiors) paying taxes or tribute. This constituted, in fact, about the only form of tribute exacted from the people. Neither were the individuals who received annual allotments permitted to alienate any portion of it. Apparently even the houses in which the people lived could not be alienated, although, today at least, a man is entitled, if he moves, to take the thatch roof of his house with him. Thus true property in land or buildings was almost if not entirely unknown among the Indians of this region, as in other parts of America, before the coming of Europeans.

It is not known whether the office of chief among the Colla

people before the Inca conquest was hereditary, as was that of the Inca ruler, or whether a chief was elected, as among the Mexicans. The list of ancient kings, given by Montesinos, and thought by some to refer to the dynasties that ruled in Tiahuanaco, records direct lineal succession in most cases. At the present time, however, both the *alcaldes* and the *ilacatas*—the police and the administrative officers respectively—of the Aymará communities are elected.

While the local organization of society was that of the consanguineal group, there had been superimposed upon this a system of government by the conquering Inca dynasty. It is somewhat difficult to distinguish what features of the government pertained to the central authority and what to the local communities; but, as the policy of the Incas was generally to leave the already existing customs and institutions of conquered peoples as far as possible undisturbed, it would seem that the central government concerned itself chiefly in the collecting of revenue and in the military organization of the country—even in this, operating, for the most part, through the recognized chiefs of the local communities. Since there are repeated references to the clan organization among the Spanish writers who describe the social institutions of the Indians and since many features of such kinship organization, characteristic of almost all American aborigines, are preserved among the Indian communities today, it would seem that the Inca's government did not at all supersede this form of polity but rather recognized the local units and ruled the country through them.

The religious life of the Collas was a mixture of a primitive animistic worship of hills, mountains, rocks, and many other natural objects and the more elevated concept of the sun as the giver of all life. There are evidences, too, of the worship of a Great Spirit, thought of as superior to all of these other deities. Reverence for ancestors also approached a form of worship. The first of these, a superstitious regard for the spirits of familiar inanimate objects, probably had most intimate influence upon their daily lives, since they lived in constant dread of the displeas-

ure of these spirits. The same is true of the Aymarás of today, who build tiny stone houses to the spirits of the hills at every high pass, throw an offering of masticated coca leaves upon overhanging cliffs along the roads, dash the blood of a slaughtered animal upon the gable of their adobe houses, spill a little of every cup of liquor which they drink, in reverence to Pachacmama (Earth Mother), and hear the movements of spirits in every rolling rock upon the hillside. The worship of the sun was probably more remote in its appeal to them, although a very natural result of the desire for its heat in the penetrating cold of their native highlands. Some of the great religious festivals were connected with the movements of the sun; and careful observations were made with astronomical instruments, constructed of masonry, to determine the equinoxes and solstice.[1] The most notable sun festival —the Intip Raymi—is still observed in many parts of the highlands but with the Christian name of St. John's Day. This occurred at the time of the winter solstice (southern hemisphere) on June 21 and was apparently a combination of harvest celebration and an attempt to bring back the sun from the most distant point of his yearly journey. In the old Spanish accounts the former feature is most prominent, but at the present time the observance consists principally of the lighting of fires in the streets, in the house yards, on the hillsides, and wherever bundles of grass or other combustible can be collected. For several days and nights, but particularly the first night, the whole country seems ablaze. Bundles of weeds and brushwood are lighted about every cottage, bonfires are made in the streets, and the bunch grass and weeds upon every hillside are lighted, continuing the ancient custom of calling back the sun, the source of heat and light and life. For several days before the solstice, trains of mules and donkeys loaded with the combustibles make their way into the towns, while for several days afterwards the valleys are filled with smoke, so dense, sometimes, as completely to shut out sight of the surrounding hills.

Among the objects of special veneration were the jaguar,

[1] See Clements Robert Markham, (113), pp. 115–116.

llama, puma, condor, and serpent, if we may judge from the appearance of these objects among their sacred symbols. Each household also had its own particular *huaca* (object of worship) or reverenced that of the ayllu to which it belonged, usually representing the person or object from which tradition said that the ancestor of their clan had sprung.

With the establishment of the Inca dynasty the worship of the sun apparently took on new importance, inasmuch as the Incas considered themselves the children of the sun, and the sun cult was quite directly connected with allegiance to the royal family. Cuzco, the Inca capital, was also the seat of the great temple of the sun, a structure whose exquisite masonry (a part of which still stands) and elaborate ornaments of gold caused wonder in all who saw them. The Island of the Sun (Isla de Titicaca) also was a place of sacred character to the Incas, and they had a temple of the sun erected there. The Incas themselves came to worship there, either because of some superstition connected with the natural Rock of the Cat, which stands upon the island, or perhaps because of the tradition that the island was the cradle of the Inca rulers themselves. It seems, however, that the island had already long had something of a sacred character before it was made a place of Inca pilgrimages. Copacabana was also a place of pilgrimages, where a huaca existed. In place of this huaca there now exists the Virgin of Copacabana, and thousands of Indians journey long distances each year to worship at this time-honored shrine. It is possible that in pre-Inca times these shrines and perhaps also Tiahuanaco were principal religious centers of the Aymarás, but at the time of the Spanish Conquest they were secondary to Cuzco, which had become the religious as well as the political capital.

APPENDIX B

THE PROBLEM OF TACNA AND ARICA

Dispute over this territory dates from the War of the Pacific (1879–1883), in which Bolivia and Peru united against Chile. Up to a few decades before that time the entire desert of Atacama which lay on the border of the three countries, had been considered practically worthless, except for the silver mines of Guantajaya and Santa Rosa near Iquique, and the boundaries were but ill defined. About the middle of the last century, however, there developed a demand in Europe for the guano which was found on the coast and among the adjacent islands. This impelled the three countries to assert their respective claims. The discovery of rich nitrate deposits (1830–1850) and the development of steam navigation—the first line on the west coast was established in 1840—greatly accentuated the interest in these hitherto valueless territories. Chile created the province of Atacama (1843), with undefined northern limits. Peru developed a state monopoly of the newly discovered resources in her desert provinces; and Bolivia, for the first time, organized an effective administration over the section that traditionally belonged to her. Both guano and nitrate were developed chiefly for export to Europe, and the trade that resulted was almost entirely maritime. The most active exploiters of these natural resources were foreigners resident in Chile or citizens of that country itself. To the Chileans the traffic in these commodities was of greatest interest, because, on their way to Europe, all the vessels trading in guano or nitrate passed the length of her thousand miles of coast and frequently put in at her ports, while to both Peru and Bolivia it meant the exploitation of resources that lay on the extreme borders of their possessions. Consequently it was Chile which first learned to prize the desert region and became most active in advances into it. Treaties of 1866 and 1874 with Bolivia pushed the Chil-

ean frontier northward from El Paposo (latitude about 25°) to latitude 24° S., just south of Antofagasta, and guaranteed Chilean citizens against the imposition of increased exportation duties in the territory between that and latitude 23°. An alleged violation of these rights, in the imposition of an additional export tax, brought about war between the two countries (1879). Peru, in compliance with a secret treaty of mutual defense which she had signed with Bolivia in 1873, was drawn into the conflict. This secret treaty was evidently intended to check Chile's aggressive advance northward and to prevent her acquiring the newly discovered wealth of the desert. The war thus sprang from economic causes, the desire of each nation to secure the greatest gain from the valuable guano and nitrate deposits.

The conflict proved disastrous to the allied nations. Chile early established her superiority on the sea and thus commanded the coast with its line of ports, upon which almost all life in the desert depended. Peru and Bolivia were unable to move their armies across the desert to attack the Chilean forces which, landing at convenient points on the coast, had overrun all the nitrate provinces and had even established themselves in the fertile oases of the Tacna and Arica valleys. Further naval successes and the decisive defeats inflicted upon the allies at the battles of the Campo de Alianza near Tacna and the Morro of Arica permitted Chile to capture Lima and dictate the terms of peace, Bolivia having already withdrawn from the war.[1]

As a result of the war Bolivia was compelled to cede to Chile her entire littoral, containing the major portion of the nitrate deposits. She became an inland country dependent upon the goodwill of her neighbors for all outlet to the sea. This lack of coast line has accentuated her already embarrassing isolation and has greatly retarded her progress.

By the treaty of Ancón (1883), which terminated the war between Peru and Chile, Peru was forced to surrender outright her southernmost province, Tarapacá, containing the rest of the

[1] See Isaiah Bowman: The Military Geography of Atacama, *Educational Bi-Monthly*, 1911, pp. 1-21.

nitrate deposits, Chile thus gaining what had apparently been her goal in the war, complete possession of these enormous sources of wealth. Since that time the export duty on nitrate has been her principal fount of national income, supplying some three-fourths of her total revenue. Chile also made a determined effort to secure the cession of Tacna and Arica, the two succeeding Peruvian provinces, not because of any natural wealth that they contained, for they were not only desert but, as far as was known, held no important mineral deposits. They offered, however, a far better protection to her recently acquired treasure than any frontier farther south and, in the hands of Peru, would be a constant menace to Chilean possession of the nitrate fields. The distance from seacoast to cordillera at this point is considerably less than it is to the south. Moreover, the fertile, irrigated valleys of Sama, Tacna, and Tarata afford supplies whereby an army could subsist independent of the sea, and they are the only valleys north of Copiapó where such is the case. The port of Arica also is a key position in this section of the coast, in that it gives easy access to the valleys mentioned above, is the most feasible entrance to Bolivia for either trade or war, and affords the most favorable point of attack against the nitrate fields of Tarapacá.

Peru, while resigning herself to the loss of the valuable mineral deposits in her southernmost province—largely developed by Chileans and containing relatively few Peruvian inhabitants, stubbornly resisted all attempts of Chile to appropriate Tacna and Arica with their old-established Peruvian towns. A compromise was finally effected whereby Chile was to occupy these two provinces for a period of ten years, at the expiration of which a plebiscite should determine their ultimate destiny. The nation favored by the plebiscite should then pay to the other 10,000,000 pesos (from $2,000,000 to $3,000,000). Unfortunately, the conditions of the plebiscite were left undefined, the two countries were later unable to agree upon satisfactory terms, and Chile continued to hold Tacna and Arica, which under her administration have become the two departments composing the province of Tacna.

Since the expiration of the ten-year period, during which time the provinces were to be held and completely administered as Chilean territory, the question of ownership has constantly agitated the two nations concerned. Its influence has also extended far beyond the bounds of these countries and has constituted a problem which at any time might throw a large part of the continent into war. More than any other problem this affair has been a source of discord in South American international relations. It has caused a multitude of attempts at forming defensive or offensive alliances among the various republics and thus creating a South American balance of power, as each of the disputants has sought to secure the support of neighbors or to align other nations against its opponent. Bolivia in particular, as the country most directly affected, has suffered both in her international affairs and in her domestic politics from the inquietude engendered by this vexing problem. Her recent revolution (1919) was brought about largely as a result of divergent views and sympathies in regard to the Chile-Peru embroglio.

Both Chile and Peru have agreed that the plebiscite provided for by the treaty of Ancón should be held. They have maintained, however, quite diverse views as to the real purpose of that vote and as to the manner in which it should be carried out. Peru has demanded that a bona fide vote should be taken to ascertain the desire of the permanent residents of the occupied provinces. She has felt confident that such a vote would restore her provinces to her, believing that the sparse population, always predominantly Peruvian, has remained loyal in spite of adverse conditions throughout the lapse of nearly forty years. Chile, on the other hand, has insisted that the plebiscite be conducted in such a way as practically to assure her permanent possession of the provinces and of late years has clearly stated that she has no intention of allowing them to pass out of her power. In fact she has indeed asserted that it was never the intention that the plebiscite should be more than a mere form of transfer whereby the national pride of the Peruvians might be spared the humiliation of an outright cession. She has held that the plebiscite is neces-

sary merely as the formal act of transfer provided by the treaty.

Since both nations wish to see the plebiscite carried out, the dispute has centered about the form in which the voting should be conducted. The history of the negotiations has been one of proposals and counterproposals, each nation seeking a form that would be acceptable to her opponent and at the same time would assure her own success in the vote. The principal questions at issue have been the following:

First, Who shall be entitled to vote? Peru claims that only Peruvians or at least bona fide residents whose residence has been established by a term of years, shall be given this right. This would include few Chileans, since the resources of the provinces are so limited that few actual settlers have entered the region since the War of the Pacific. By far the greater part of the Chileans found in the territory are officials or members of military forces stationed there. Most of both of these classes are transients. There are many more or less permanent Bolivian residents, constituting perhaps half of the population other than Peruvians. These Peru could probably count upon to vote for her. Chile insists that all inhabitants, even those with a short residence of a few months, shall be allowed to vote, not excluding Chilean officials and soldiers. This point Peru has hitherto been willing to arbitrate, while Chile has not.

Second, By what authority shall the plebiscite be conducted? The two nations have agreed that each should have a representative upon the commission named to carry out the vote. Chile has insisted upon her right to preside over such a commission, since the departments are actually under her administration. Peru has been willing that any neutral representative should preside, but not a Chilean. She has been prepared to arbitrate this point also, while Chile has not.

Third, What shall be the method of balloting? Peru wishes the vote to be public, Chile that it should be secret. Peru is also willing to arbitrate this point.

Fourth, In what form shall the 10,000,000 pesos due to the loser be paid? This apparently has never concerned Peru since

she has not doubted the result of a popular vote. Chile has found all guarantees offered by Peru acceptable.

Controversy over these points was maintained almost constantly from 1892–1894 (the final years of the ten-year period) until 1901. Negotiations were often seriously interrupted by changes of ministry in Chile and by unstable political conditions in Peru. The nearest approach to a settlement was reached in 1897 in the Billinghurst-Latorre Convention. In this document the two nations agreed to submit to the Queen of Spain as arbitrator the questions numbered one and three above. They also agreed that the plebiscite should be conducted by a commission over which a neutral representative should preside and that the 10,000,000 pesos should be paid by installments within a period of four years. This treaty was ratified promptly by the Peruvian Congress and by the Chilean Senate but was delayed in the Chilean Chamber of Deputies and finally shelved. The usual explanation of Chile's willingness to settle at that time her controversy with Peru, is that the Chile-Argentine boundary question was just then threatening trouble and there was a very natural desire to dispose of all possibilities of complications on the west coast. Before the convention was completely ratified, however, the crisis had passed, and it is supposed that Chile found it no longer necessary to accede to Peru's demands.

After the failure to reach a settlement Peru severed diplomatic relations with Chile and for several years had no representative at Santiago. Relations were finally renewed, only to be broken again in 1910 when another attempt at settlement failed.

In the meantime Chile had actively carried on attempts to develop the two departments left indefinitely under her jurisdiction. In compliance with a treaty with Bolivia in 1904, she constructed the Arica-La Paz railway, which forms part of her system of state lines. She has organized (1884) the two provinces as one political unit which she now calls the province of Tacna and which she divides into the two departments of Tacna and Arica.

The Department of Tacna is divided into two Municipios—

those of Tacna and Tarata. The latter comprises the *subdelegaciones* of Pocollai, Pachia, Palca, Tarata, Sama, and Calana and includes practically all the territory of the department save a small portion near the town of Tacna. This arrangement is confusing, since the Peruvian organization also included a Province of Tarata which comprised the whole basin of the Sama in the Cordillera but not the lower country traversed by that river south of Caribaya. In 1884 Chile occupied the territory up to the Río Cano, which is the most westerly head stream of the Sama, claiming this interpretation of the treaty and thus going beyond the limits of the Peruvian province of Tacna.

The port of Arica is being improved, and the hills about it have been fortified. Education is being fostered in accordance with the Chilean system. Ecclesiastical authority has been transferred from Peruvian to Chilean priests, many of the Peruvian priests having been expelled as instigators of disloyalty to Chile. The colonization of the departments by Chileans has been attempted, although little has so far been accomplished.

In 1918 it seemed that war would break out between the two nations as a result of Chilean activities in the "captive provinces." But a note from President Wilson, urging them to avoid an appeal to arms was effective in averting actual hostilities.

At present (1922), upon invitation from President Harding, the two claimants have agreed to meet in Washington in an attempt to reach a satisfactory solution of the matter. Prior to this conference nothing has transpired publicly to indicate that the positions of the two governments have altered, viz., that Peru has refused to surrender her sovereignty; Chile has stated her determination to retain the territory; and no agreement has been reached regarding the plebiscite. Compromise would therefore seem to be essential to the success of the conference.

The entire problem of Tacna and Arica has been complicated by the desire of Bolivia to secure an outlet to the sea. Arica has always been her most natural port, and a large part of her foreign trade has been carried on through this gateway; formerly by mule and llama train, more recently by railway. Since the loss

of her littoral and her own ports of Antofagasta, Cobija, and Mejillones she has come to covet the port of Arica and a strip of territory leading back from the coast to her mountain boundary. In 1895 a secret treaty was actually signed with Chile, in which the latter country agreed to turn over Tacna and Arica to Bolivia in case the plebiscite resulted in favor of Chile. The treaty failed to obtain ratification in the Chilean Congress, but the effort has been renewed in a more or less open way on later occasions.

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APPENDIX D

CONVERSION TABLES

Table I

Millimeters into Inches

1 mm.—0.03937 inch.

Mm.	0	1	2	3	4	5	6	7	8	9
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
0	0.0000	0.0394	0.0787	0.1181	0.1575	0.1968	0.2362	0.2756	0.3150	0.3543
10	0.3937	0.4331	0.4724	0.5118	0.5512	0.5906	0.6299	0.6693	0.7087	0.7480
20	0.7874	0.8268	0.8661	0.9055	0.9449	0.9842	1.0236	1.0630	1.1024	1.1417
30	1.1811	1.2205	1.2598	1.2992	1.3386	1.3780	1.4173	1.4567	1.4961	1.5354
40	1.5748	1.6142	1.6535	1.6929	1.7323	1.7716	1.8110	1.8504	1.8898	1.9291
50	1.9685	2.0079	2.0472	2.0866	2.1260	2.1654	2.2047	2.2441	2.2835	2.3228
60	2.3622	2.4016	2.4409	2.4803	2.5197	2.5590	2.5984	2.6378	2.6772	2.7165
70	2.7559	2.7953	2.8346	2.8740	2.9134	2.9528	2.9921	3.0315	3.0709	3.1102
80	3.1496	3.1890	3.2283	3.2677	3.3071	3.3464	3.3858	3.4252	3.4646	3.5039
90	3.5433	3.5828	3.6220	3.6614	3.7008	3.7402	3.7795	3.8189	3.8583	3.8976

Millimeters	Inches	Millimeters	Inches	Millimeters	Inches
100	3.9370	500	19.6850	800	31.496
200	7.8740	600	23.6220	900	35.4330
300	11.8110	700	27.559	1000	39.3700
400	15.7480				

Table II

Meters into Feet

1 meter—39.3700 inches—3.280833 feet.

M.	0	1	2	3	4	5	6	7	8	9
	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet
0	0.00	3.28	6.56	9.84	13.12	16.40	19.68	22.97	26.25	29.53
10	32.81	36.09	39.37	42.65	45.93	49.21	52.49	55.77	59.05	62.34
20	65.62	68.90	72.18	75.46	78.74	82.02	85.30	88.58	1.866	95.14
30	98.42	101.71	104.99	108.27	111.55	114.83	118.11	121.39	124.67	127.95
40	131.23	134.51	137.79	141.08	144.36	147.64	150.92	154.20	157.48	160.76
50	164.04	167.32	170.60	173.88	177.16	180.45	183.73	187.01	190.29	193.57
60	196.85	200.13	203.41	206.69	209.97	213.25	216.53	219.82	223.10	226.38
70	229.66	232.94	236.22	239.50	242.78	246.06	249.34	252.62	255.90	259.19
80	262.47	265.75	269.03	272.31	275.59	278.87	282.15	285.43	288.71	291.99
90	295.27	298.56	301.84	305.12	308.40	311.68	314.96	318.24	321.52	324.80

Meters	Feet	Meters	Feet	Meters	Feet
		800	2624.7		
100	328.08	900	2952.7	4000	13123.3
200	656.17	1000	3280.8	4500	14763.7
300	984.25	1500	4921.2	5000	16404.2
400	1312.33	2000	6561.7	5500	18044.6
500	1640.42	2500	8202.1	6000	19684.8
600	1968.50	3000	9842.5	6500	21325.2
700	2296.6	3500	11482.9	7000	22965.6

Table III

Kilometers into Miles

1 kilometer—0.621370 mile

Km.	0	1	2	3	4	5	6	7	8	9
	Mi.	Mi.	Mi.	Mi.	Mi.	Mi.	Mi.	Mi.	Mi.	Mi.
0	0.0	0.6	1.2	1.9	2.5	3.1	3.7	4.3	5.0	5.6
10	6.2	6.8	7.5	8.1	8.7	9.3	9.9	10.6	11.2	11.8
20	12.4	13.0	13.7	14.3	14.9	15.5	16.2	16.8	17.4	18.0
30	18.6	19.3	19.9	20.5	21.1	21.7	22.4	23.0	23.6	24.2
40	24.9	25.5	26.1	26.7	27.3	28.0	28.6	29.2	29.8	30.4
50	31.1	31.7	32.3	32.9	33.6	34.2	34.8	35.4	36.0	36.7
60	37.3	37.9	38.5	39.1	39.8	40.4	41.0	41.6	42.3	42.9
70	43.5	44.1	44.7	45.4	46.0	46.6	47.2	47.8	48.5	49.1
80	49.7	50.3	51.0	51.6	52.2	52.8	53.4	54.1	54.7	55.3
90	55.9	56.5	57.2	57.8	58.4	59.0	59.7	60.3	60.9	61.5

Kilometers	Miles	Kilometers	Miles	Kilometers	Miles
100	62.1	600	372.8	2000	1242.7
200	124.3	700	435.0	3000	1864.1
300	186.4	800	497.1	4000	2485.5
400	248.5	900	559.2	5000	3106.8
500	310.7	1000	621.4		

Table IV

Square Kilometers into Square Miles

1 km.²—0.386116 mile²

Km.²	0	1	2	3	4	5	6	7	8	9
	Mi.²	Mi.²	Mi.²	Mi.²	Mi.²	Mi.²	Mi.²	Mi.²	Mi.²	Mi.²
0	0.000	0.386	0.772	1.158	1.545	1.931	2.317	2.703	3.089	3.475
10	3.861	4.247	4.633	5.020	5.406	5.792	6.178	6.564	6.950	7.336
20	7.722	8.108	8.495	8.881	9.267	9.653	10.039	10.425	10.811	11.197
30	11.584	11.970	12.356	12.742	13.128	13.514	13.900	14.286	14.672	15.059
40	15.445	15.831	16.217	16.603	16.989	17.375	17.761	18.148	18.534	18.920
50	19.306	19.692	20.078	20.464	20.850	21.236	21.623	22.009	22.395	22.781
60	23.167	23.553	23.939	24.325	24.711	25.098	25.484	25.870	26.256	26.642
70	27.028	27.414	27.800	28.187	28.573	28.959	29.345	29.731	30.117	30.503
80	30.889	31.275	31.662	32.048	32.434	32.820	33.206	33.592	33.978	34.364
90	34.750	35.137	35.523	35.909	36.295	36.681	37.067	37.453	37.839	38.226

Km.²	Mile ²	Km. ²	Mile ²
100	38.61	600	231.67
200	77.22	700	270.28
300	115.84	800	308.89
400	154.45	900	347.50
500	193.06	1000	386.10

Table V

Hectares into Acres

Hectares	Acres	Hectares	Acres
1	2.471	6	14.826
2	4.942	7	17.297
3	7.413	8	19.768
4	9.884	9	22.239
5	12.355	10	24.710

Table VI

Centigrade Scale to Fahrenheit

Cg.	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
°	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
+	+	+	+	+	+	+	+	+	+	+
60	140.00	140.18	140.36	140.54	140.72	140.90	141.08	141.26	141.44	141.62
59	138.20	138.38	138.56	138.74	138.92	139.10	139.28	139.46	139.64	139.82
58	136.40	136.58	136.76	136.94	137.12	137.30	137.48	137.66	137.84	138.02
57	134.60	134.78	134.96	135.14	135.32	135.50	135.68	135.86	136.04	136.22
56	132.80	132.98	133.16	133.34	133.52	133.70	133.88	134.06	134.24	134.42
55	131.00	131.18	131.36	131.54	131.72	131.90	132.08	132.26	132.44	132.62
54	129.20	129.38	129.56	129.74	129.92	130.10	130.28	130.46	130.64	130.82
53	127.40	127.58	127.76	127.94	128.12	128.30	128.48	128.66	128.84	129.02
52	125.60	125.78	125.96	126.14	126.32	126.50	126.68	126.86	127.04	127.22
51	123.80	123.98	124.16	124.34	124.52	124.70	124.88	125.06	125.24	125.42
+	+	+	+	+	+	+	+	+	+	+
50	122.00	122.18	122.36	122.54	122.72	122.90	123.08	123.26	123.44	123.62
49	120.20	120.38	120.56	120.74	120.92	121.10	121.28	121.46	121.64	121.82
48	118.40	118.58	118.76	118.94	119.12	119.30	119.48	119.66	119.84	120.02
47	116.60	116.78	116.96	117.14	117.32	117.50	117.68	117.86	118.04	118.22
46	114.80	114.98	115.16	115.34	115.52	115.70	115.88	116.06	116.24	116.42
45	113.00	113.18	113.36	113.54	113.72	113.90	114.08	114.26	114.44	114.62
44	111.20	111.38	111.56	111.74	111.92	112.10	112.28	112.46	112.64	112.82
43	109.40	109.58	109.76	109.94	110.12	110.30	110.48	110.66	110.84	111.02
42	107.60	107.78	107.96	108.14	108.32	108.50	108.68	108.86	109.04	109.22
41	105.80	105.98	106.16	106.34	106.52	106.70	106.88	107.06	107.24	107.42
+	+	+	+	+	+	+	+	+	+	+
40	104.00	104.18	104.36	104.54	104.72	104.90	105.08	105.26	105.44	105.62
39	102.20	102.38	102.56	102.74	102.92	103.10	103.28	103.46	103.64	103.82
38	100.40	100.58	100.76	100.94	101.12	101.30	101.48	101.66	101.84	102.02
37	98.60	98.78	98.96	99.14	99.32	99.50	99.68	99.86	100.04	100.22
36	96.80	96.98	97.16	97.34	97.52	97.70	97.88	98.06	98.24	98.42
35	95.00	95.18	95.36	95.54	95.72	95.90	96.08	96.26	96.44	96.62
34	93.20	93.38	93.56	93.74	93.92	94.10	94.28	94.46	94.64	94.82
33	91.40	91.58	91.76	91.94	92.12	92.30	92.48	92.66	92.84	93.02
32	89.60	89.78	89.96	90.14	90.32	90.50	90.68	90.86	91.04	91.22
31	87.80	87.98	88.16	88.34	88.52	88.70	88.88	89.06	89.24	89.42

Table VI

(Continued)

Centigrade Scale to Fahrenheit

Cg.	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
°	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
+	+	+	+	+	+	+	+	+	+	+
30	86.00	86.18	86.36	86.54	86.72	86.90	87.08	87.26	87.44	87.62
29	84.20	84.38	84.56	84.74	84.92	85.10	85.28	85.46	85.64	85.82
28	82.40	82.58	82.76	82.94	83.12	83.30	83.48	83.66	83.84	84.02
27	80.60	80.78	80.96	81.14	81.32	81.50	81.68	81.86	82.04	82.22
26	78.80	78.98	79.16	79.34	79.52	79.70	79.88	80.06	80.24	80.42
25	77.00	77.18	77.36	77.54	77.72	77.90	78.08	78.26	78.44	78.62
24	75.20	75.38	75.56	75.74	75.92	76.10	76.28	76.46	76.64	76.82
23	73.40	73.58	73.76	73.94	74.12	74.30	74.48	74.66	74.84	75.02
22	71.60	71.78	71.96	72.14	72.32	72.50	72.68	72.86	73.04	73.22
21	69.80	69.98	70.16	70.34	70.52	70.70	70.88	71.06	71.24	71.42
+	+	+	+	+	+	+	+	+	+	+
20	68.00	68.18	68.36	68.54	68.72	68.90	69.08	69.26	69.44	69.62
19	66.20	66.38	66.56	66.74	66.92	67.10	67.28	67.46	67.64	67.82
18	64.40	64.58	64.76	64.94	64.12	65.30	65.48	65.66	65.84	66.02
17	62.60	62.78	62.96	63.14	63.32	63.50	63.68	63.86	64.04	64.22
16	60.80	60.98	61.16	61.34	61.52	61.70	61.88	62.06	62.24	62.42
15	59.00	59.18	59.36	59.54	59.72	59.90	60.08	60.26	60.44	60.62
14	57.20	57.38	57.56	57.74	57.92	58.10	58.28	58.46	58.64	58.82
13	55.40	55.58	55.76	55.94	56.12	56.30	56.48	56.66	56.84	57.02
12	53.60	53.78	53.96	54.14	54.32	54.50	54.68	54.86	55.04	55.22
11	51.80	51.98	52.16	52.34	52.52	52.70	52.88	53.06	53.24	53.42
+	+	+	+	+	+	+	+	+	+	+
10	50.00	50.18	50.36	50.54	50.72	50.90	51.08	51.26	51.44	51.62
9	48.20	48.38	48.56	48.74	48.92	49.10	49.28	49.46	49.64	49.82
8	46.40	46.58	46.76	46.94	47.12	47.30	47.48	47.66	47.84	48.02
7	44.60	44.78	44.96	45.14	45.32	45.50	45.68	45.86	46.04	46.22
6	42.80	42.98	43.16	43.34	43.52	43.70	43.88	44.06	44.24	44.42
5	41.00	41.18	41.36	41.54	41.72	41.90	42.08	42.26	42.44	42.62
4	39.20	39.38	39.56	39.74	39.92	40.10	40.28	40.46	40.64	40.82
3	37.40	37.58	37.76	37.94	38.12	38.30	38.48	38.66	38.84	39.02
2	35.60	35.78	35.96	36.14	36.32	36.50	36.68	36.86	37.04	37.22
1	33.80	33.98	34.16	34.34	34.52	34.70	34.88	35.06	35.24	35.42
+	+	+	+	+	+	+	+	+	+	+
0	32.00	32.18	32.36	32.54	32.72	32.90	33.08	33.26	33.44	33.62

Table VI

(*Continued*)

Centigrade Scale to Fahrenheit

Cg.	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
°	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
−	+	+	+	+	+	+	+	+	+	+
0	32.00	31.82	31.64	31.46	31.28	31.10	30.92	30.74	30.56	30.38
1	30.20	30.02	29.84	29.66	29.48	29.30	29.12	28.94	28.76	28.58
2	28.40	28.22	28.04	27.86	27.68	27.50	27.32	27.14	26.96	26.78
3	26.60	26.42	26.24	26.06	25.88	25.70	25.52	25.34	25.16	24.98
4	24.80	24.62	24.44	24.26	24.08	23.90	23.72	23.54	23.36	23.18
5	23.00	22.82	22.64	22.46	22.28	22.10	21.92	21.74	21.56	21.38
6	21.20	21.02	20.84	20.66	20.48	20.30	20.12	19.94	19.76	19.58
7	19.40	19.22	19.04	18.86	18.68	18.50	18.32	18.14	17.96	17.78
8	17.60	17.42	17.24	17.06	16.88	16.70	16.52	16.34	16.16	15.98
9	15.80	15.62	15.44	15.26	15.08	14.90	14.72	14.54	14.36	14.18
−	+	+	+	+	+	+	+	+	+	+
10	14.00	13.82	13.64	13.46	13.28	13.10	12.92	12.74	12.56	12.38
11	12.20	12.02	11.84	11.66	11.48	11.30	11.12	10.94	10.76	10.58
12	10.40	10.22	10.04	9.86	9.68	9.50	9.32	9.14	8.96	8.78
13	8.60	8.42	8.24	8.06	7.88	7.70	7.52	7.34	7.16	6.98
14	6.80	6.62	6.44	6.26	6.08	5.90	5.72	5.54	5.36	5.18
−	+	+	+	+	+	+	+	+	+	+
15	5.00	4.82	4.64	4.46	4.28	4.10	3.92	3.74	3.56	3.38
	+	+	+	+	+	+	+	+	+	+
16	3.20	3.02	2.84	2.66	2.48	2.30	2.12	1.94	1.76	1.58
	+	+	+	+	+	+	+	+	−	−
17	1.40	1.22	1.04	0.86	0.68	0.50	0.32	0.14	0.04	0.22
	−	−	−	−	−	−	−	−	−	−
18	0.40	0.58	0.76	0.94	1.12	1.30	1.48	1.66	1.84	2.02
	−	−	−	−	−	−	−	−	−	−
19	2.20	2.38	2.56	2.74	2.92	3.10	3.28	3.46	3.64	3.82
−	−	−	−	−	−	−	−	−	−	−
20	4.00	4.18	4.36	4.54	4.72	4.90	5.08	5.26	5.44	5.62
21	5.80	5.98	6.16	6.34	6.52	6.70	6.88	7.06	7.24	7.42
22	7.60	7.78	7.96	8.14	8.32	8.50	8.68	8.86	9.04	9.22
23	9.40	9.58	9.76	9.94	10.12	10.30	10.48	10.66	10.84	11.02
24	11.20	11.38	11.56	11.74	11.92	12.10	12.28	12.46	12.64	12.82
25	13.00	13.18	13.36	13.54	13.72	13.96	14.08	14.26	14.44	14.62
26	14.80	14.98	15.16	15.34	15.52	15.70	15.88	16.06	16.24	16.42
27	16.60	16.78	16.96	17.14	17.32	17.50	17.68	17.86	18.04	18.22
28	18.40	18.58	18.76	18.94	19.12	19.30	19.48	19.66	19.84	20.02
29	20.20	20.38	20.56	20.74	20.92	21.10	21.28	21.46	21.64	21.82
−	−	−	−	−	−	−	−	−	−	−
30	22.00	22.18	22.36	22.54	22.72	22.90	23.08	23.26	23.44	23.62

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